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ABACAst: An AI-Powered Decision Support Framework for Sustainable Abaca Production

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ABSTRACT: Abaca production remains economically important in the Philippines, yet farmers face persistent challenges in cultivar selection, disease monitoring, and farm management decision-making. This study developed ABACAst, an AI-powered decision support framework for sustainable abaca production in Lanuza, Surigao del Sur. Using a descriptive-developmental design and iterative system development approach, the framework integrated farmer-provided data, rule-based recommendations, cultivar information, and ISO/IEC 25010-based evaluation. Results showed satisfactory predictive performance, with 87% accuracy, 85% precision, 83% recall, and 84% F1-score. The ISO/IEC 25010 overall average was 3.88/5.00, indicating favorable system quality and practical decision-support potential.

KEYWORDS: Abaca production; decision support system; sustainable agriculture; rule-based recommendation; ISO/IEC 25010

I. INTRODUCTION

Abaca (*Musa textilis*), internationally known as Manila hemp, is one of the most valuable natural fiber crops in the Philippines because of its strength, flexibility, and wide industrial use. It is used in specialty paper, cordage, ropes, handicrafts, textiles, and other high-value fiber products. Because of these applications, abaca production remains significant not only to agricultural livelihood but also to export-oriented rural development. Previous literature identifies abaca as a Philippine fiber crop with important uses in cordage, clothing, handicrafts, and specialty papers such as currency notes, filter papers, stencil papers, and tea bags (Lalusin & Antaran, 1996). In the Caraga Region, abaca production has also been documented as an important agricultural activity involving identified production areas, farmer interviews, geotagging, focus group discussions, and stakeholder validation (Sagocsoc et al., 2023).

Despite this economic value, many abaca farmers continue to experience production-related challenges, including disease occurrence, cultivar selection problems, inconsistent farm records, limited access to technical information, and difficulty translating agricultural references into practical farm decisions. These challenges are particularly evident in smallholder contexts where decisions often depend on experience, locally available advice, and limited extension services. Abaca production studies in Caraga emphasize the need to examine production areas, farming practices, farmer conditions, and stakeholder concerns to understand actual field-level constraints (Sagocsoc et al., 2023). In the attached full paper, Lanuza, Surigao del Sur was identified as a relevant research locale because of its concentration of abaca farms and its dependence on abaca as a source of livelihood.

The digital transformation of agriculture provides an opportunity to strengthen farm-level decision-making through decision support systems, digital advisory tools, and data-driven platforms. However, smallholder farmers often face limitations related to connectivity, affordability, digital literacy, and infrastructure. For this reason, agricultural systems intended for rural communities should be practical, lightweight, interpretable, and directly aligned with local farming conditions.

Decision support systems can organize fragmented agricultural information and convert farm data into actionable recommendations. In abaca production, such systems can assist farmers in cultivar profiling, disease-related guidance, farm monitoring, fiber quality tracking, and sustainable crop management. Nevertheless, there remains a practical gap between available technical information and the daily decision-making needs of farmers. ABACAst was developed to address this gap by integrating farmer-provided data, cultivar information, disease reporting, rule-based recommendation logic, and system monitoring into one accessible platform.

This study aimed to design, develop, implement, and evaluate ABACAst as an AI-powered decision support framework for sustainable abaca production. Specifically, it sought to: (1) design a decision support framework for organizing abaca production data; (2) develop rule-based recommendation functions for cultivar profiling, disease support, and crop-care guidance; (3) implement a prototype system that supports monitoring, prediction, and recommendation; and (4) evaluate the system using algorithmic performance metrics and ISO/IEC 25010 software quality criteria.

II. LITERATURE SURVEY

Digital agriculture and smallholder decision support

Digital agriculture has moved from simple farm record keeping toward advisory delivery, monitoring, analytics, and decision support for farm management. Zhai et al. (2020) emphasized that agricultural decision support systems are increasingly important in Agriculture 4.0 because they process farming data such as meteorological information, soil conditions, land use, and market-related information to assist farmers in decision-making. Similarly, Mouratiadou et al. (2023) explained that digital agricultural knowledge systems can connect scientific knowledge, field data, and stakeholder needs to support diversified and sustainable agricultural systems.

For smallholder farmers, digital tools can improve access to agricultural information, support planning, and improve productivity. Choruma et al. (2024) found that digital technologies used by smallholder farmers include digital extension services, market information tools, and advisory platforms, but their adoption remains constrained by limited internet connectivity, low digital literacy, infrastructure limitations, and affordability issues. Gumbi et al. (2023) likewise argued that sustainable digital agriculture for smallholder farmers requires an ecosystem perspective that considers users, infrastructure, institutions, data, and local implementation conditions. These findings are relevant to ABACAst because abaca farmers in rural communities require a system that is practical, understandable, and usable despite resource limitations.

Smallholder farming also faces economic, environmental, and climate-related pressures that affect productivity and livelihood stability. Touch et al. (2024) reported that smallholders experience multiple challenges, including climate vulnerability, declining productivity, and income-related constraints, and therefore require interventions tailored to their specific farming contexts. In this regard, localized decision-support tools such as ABACAst can help bridge the gap between available agricultural information and the actual decision-making needs of farmers.

AI and rule-based recommendation systems in agriculture

Artificial intelligence and decision-support models are increasingly used in agriculture for crop recommendation, disease detection, yield prediction, input management, and resource optimization. Senapaty et al. (2024) demonstrated that machine learning-based decision support systems can assist farmers in making better crop-related decisions by analyzing agricultural datasets and generating crop recommendations. Aijaz et al. (2025) further noted that AI contributes to crop management by enabling real-time monitoring, predictive analytics, and improved resource optimization.

However, while advanced machine learning models can provide adaptive predictive capability, they often require large, accurate, and reliable datasets. In local agricultural contexts where data may be limited or inconsistent, rule-based and interpretable systems remain useful because they generate transparent and explainable recommendations. Ali et al. (2023) emphasized that explainability is essential in AI systems because users need to understand the reasoning behind model outputs to build trust in AI-supported decision-making. This is particularly important in agriculture, where farmers and technicians must be able to interpret system recommendations before applying them in actual farm conditions.

Decision-support systems for sustainable agriculture must also consider uncertainty in farming environments. Barons et al. (2024) demonstrated that decision support systems can combine large datasets, pesticide-use information, and expert knowledge to support agricultural decision-making under uncertain policy and production conditions. Zhai et al. (2020) also identified accessibility, usability, interoperability, and scalability as important challenges for agricultural decision support systems. These findings justify the design direction of ABACAst, which uses rule-based and patternrecognition logic rather than heavy computational models, making it more suitable for rural abaca farming communities.

Abaca production and sustainable farm management

Abaca (Musa textilis) remains one of the most important natural fiber crops in the Philippines due to its use in specialty paper, cordage, handicrafts, textiles, and other industrial products. Sagocsoc et al. (2023) documented abaca production and farming practices in the Caraga Region and identified the continuing relevance of abaca farming to rural agricultural livelihoods. Galvez et al. (2021) also emphasized the importance of abaca genomic resources for improving agronomic performance, fiber quality, and disease resistance.

Sustainable abaca production requires accurate cultivar selection, disease monitoring, fiber quality assessment, and appropriate farm management. Patayon et al. (2021) demonstrated the potential of deep learning models for automatic identification of Abaca Bunchy Top Disease, showing that artificial intelligence can be applied to economically important crops such as abaca. Although ABACAst does not rely solely on deep learning, its decision-support structure aligns with the broader movement toward intelligent and data-informed agricultural systems.

Abaca disease monitoring is particularly important because viral diseases remain a major limitation in abaca production. Mendoza et al. (2024) discussed the importance of sensitive detection methods for bunchy top virus, a destructive disease affecting banana and related crops in the Philippines. This supports the need for digital tools that can help organize disease reports, support early warning, and guide farmers toward appropriate management actions. In this context, ABACAst contributes by providing modules for disease reporting, farmer record management, abaca variety information, fiber quality monitoring, recommendation generation, and sustainability guidance.

Software quality evaluation using ISO/IEC 25010

Software quality evaluation is essential in determining whether a developed system meets user expectations and technical requirements. ISO/IEC 25010 defines a product quality model applicable to ICT and software products and provides characteristics for specifying, measuring, and evaluating software quality (International Organization for Standardization, 2023). These characteristics include functional suitability, performance efficiency, compatibility, usability, reliability, security, maintainability, and portability.

Several recent studies have applied ISO/IEC 25010 to evaluate digital and mobile systems. Moumane et al. (2024) used ISO/IEC 25010 and ISO/IEC 25023 to evaluate three reproductive health mobile applications, showing that the model can identify strengths and weaknesses in mobile system quality. Rojas et al. (2025) also showed through bibliometric analysis that ISO/IEC 25010 continues to be widely used across software evaluation studies in public administration, education, healthcare, and other fields.

In the context of ABACAst, ISO/IEC 25010 is appropriate because agricultural decisionsupport systems must not only provide recommendations but must also be usable, efficient, compatible, reliable, and secure. Farmers and agricultural stakeholders are more likely to adopt a digital system when it is easy to use, responsive, dependable, and able to protect user and farm information. Therefore, evaluating ABACAst using ISO/IEC 25010 provides a structured basis for assessing its technical quality and practical acceptability.

Synthesis of the literature

The reviewed studies show that digital agriculture, artificial intelligence, and decision-support systems can improve farm management by transforming raw data into useful recommendations. However, the literature also reveals that many agricultural technologies remain difficult to adopt in smallholder contexts because of limited internet access, low digital literacy, infrastructure constraints, and lack of localized design. In abaca production, there remains a need for a practical system that connects cultivar information, disease monitoring, farm records, fiber quality, and sustainability practices into one accessible platform.

ABACAst responds to this gap by providing an AI-powered and rule-based decision-support framework specifically designed for sustainable abaca production. Unlike generic agricultural systems, ABACAst is localized for abaca farmers and evaluated using both predictive performance metrics and ISO/IEC 25010 software quality criteria. This makes the study relevant to agricultural informatics, smart farming, and sustainable crop management.Synthesis and research gap

The reviewed literature indicates that digital agriculture and decision-support systems can improve farm-level decision-making when systems are localized, practical, and user-centered. However, many existing agricultural systems are either

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too generic for crop-specific decision-making or too technically complex for smallholder settings. In abaca production, there is a need for a low-cost and interpretable framework that integrates cultivar data, farm records, disease-related inputs, sustainability guidance, and recommendation logic. ABACAst addresses this gap by providing a localized decision-support framework for sustainable abaca production in Lanuza, Surigao del Sur.

III. METHODOLOGY / APPROACH

Research design

This study employed a descriptive-developmental research design. The developmental component focused on designing and implementing ABACAst, while the descriptive component evaluated system performance, user acceptability, and software quality. This design was appropriate because the study involved both system development and empirical evaluation with actual users and stakeholders.

System development approach

The system was developed using the iterative model of the Systems Development Life Cycle. The development process involved planning, requirements analysis, design, implementation, testing, evaluation, and deployment. The iterative approach allowed the researchers to refine system modules based on farmer needs, stakeholder feedback, and issues observed during testing.

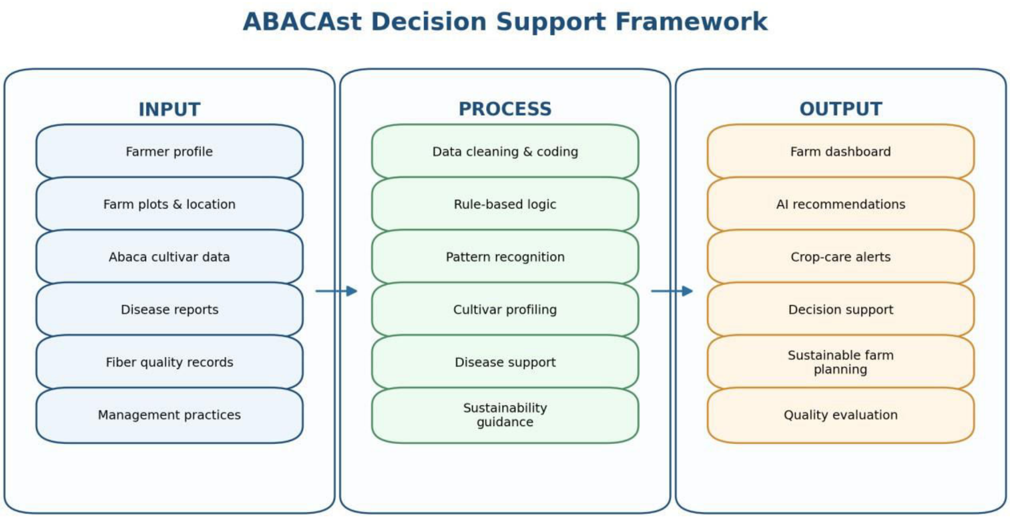

Figure 1. Conceptual framework of ABACAst using an input-process-output structure.

The figure shows the ABACAst Decision Support Framework using an Input–Process–Output (IPO) model. The system gathers farm data such as farmer profiles, farm locations, cultivar data, disease reports, fiber quality records, and management practices. These inputs are processed through data cleaning, rule-based logic, pattern recognition, cultivar profiling, disease support, and sustainability guidance. The system then generates outputs such as a farm dashboard, AI recommendations, crop-care alerts, decision support, sustainable farm planning, and quality evaluation to help farmers make informed decisions for sustainable abaca production.

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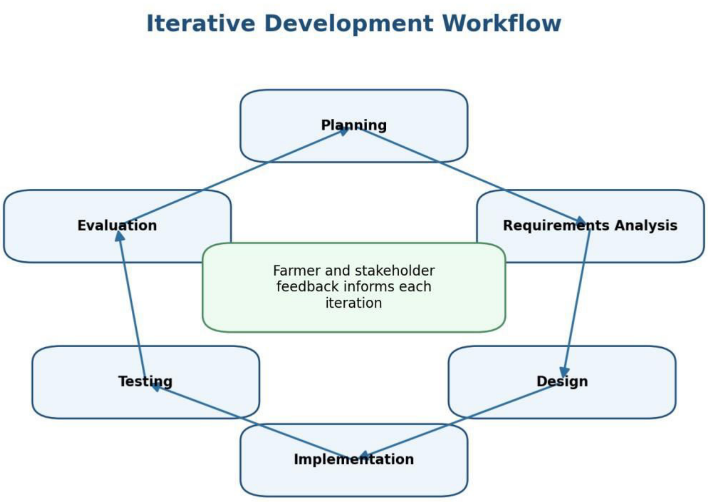

Figure 2. Iterative development model used in the design, testing, and refinement of ABACAst.

The figure shows the Iterative Development Workflow used in developing ABACAst. It follows repeated cycles of planning, requirements analysis, design, implementation, testing, and evaluation. Farmer and stakeholder feedback informs each iteration, allowing the system to be continuously refined based on actual user needs and farming conditions.

System framework and architecture

ABACAst was designed as a decision-support framework that collects, organizes, processes, and transforms farm-related information into practical recommendations. Input data include farmer profiles, farm plot records, abaca variety information, disease reports, fiber quality data, and sustainability practices. These inputs are processed using data cleaning, coding, rule-based logic, and pattern recognition. The final outputs include farm monitoring dashboards, crop-care alerts, cultivar guidance, disease-related recommendations, and decision-support insights.

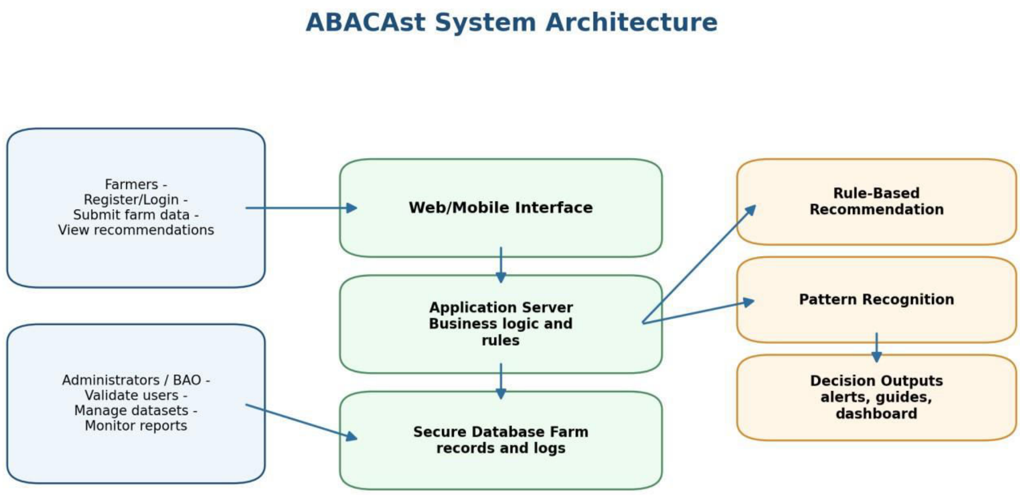

Figure 3. System architecture of ABACAst showing user inputs, secure storage, rule-based logic, and decision-support outputs.

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The figure shows the ABACAst System Architecture. Farmers access the system through the web/mobile interface to register, log in, submit farm data, and view recommendations. Administrators and Barangay Agriculture Officers validate users, manage datasets, and monitor reports. The application server processes the data using business rules, rule-based recommendation, and pattern recognition, while the secure database stores farm records and system logs. The system then generates decision outputs such as alerts, guides, and dashboard results.

Respondents and sampling technique

The respondents included abaca farmers, barangay agriculture officers, and system administrators from Lanuza, Surigao del Sur. Farmers represented the primary user group because they were the direct beneficiaries of the decision-support system. Barangay agriculture officers and administrators provided additional perspectives on technical use, agricultural relevance, and system management. Purposive sampling was used to select respondents with direct involvement in abaca production, agricultural support, or system evaluation.

Research instruments and data collection

The main instruments were the ABACAst prototype system, ISO/IEC 25010-based evaluation questionnaire, interview guide, observation notes, and system logs. The questionnaire assessed functional suitability, performance efficiency, compatibility, usability, reliability, and security. Data were gathered through field observation, system testing, stakeholder feedback, and structured evaluation. Farmers and agricultural stakeholders interacted with the system and evaluated its relevance, clarity, usability, and performance.

Algorithmic and statistical treatment

ABACAst used rule-based predictive logic and pattern-recognition methods to generate decision-support recommendations. The predictive component was evaluated using accuracy, precision, recall, and F1-score. Descriptive statistics were used to summarize ISO/IEC 25010 evaluation results. Mean scores and percentages were computed to determine perceived system quality and overall acceptability.

Ethical considerations

The study observed ethical standards in conducting system evaluation and collecting data. Participants were informed about the purpose of the study and their participation. Personal and farmrelated information was handled confidentially. The system was presented as a decision-support tool intended to assist, not replace, farmer judgment and the professional guidance of agricultural technicians.

IV. RESULTS AND DISCUSSION

Algorithm performance evaluation

The predictive component of ABACAst was evaluated using four standard metrics: accuracy, precision, recall, and F1-score. Results showed 87% accuracy, 85% precision, 83% recall, and 84% F1-score. These results indicate that the system produced generally reliable recommendations using available farm data and rule-based logic.

Evaluation Metric	Value (%)
Accuracy	87
Precision	85
Recall	83
F1-score	84

Table 1. Algorithm performance evaluation.

The algorithm achieved an accuracy of 87%, indicating that ABACAst generated correct recommendations in most test cases. The precision score of 85% shows that most recommendations were relevant, while the recall score of 83% indicates that the system was able to identify most applicable conditions. The F1-score of 84% shows a balanced performance between precision and recall.

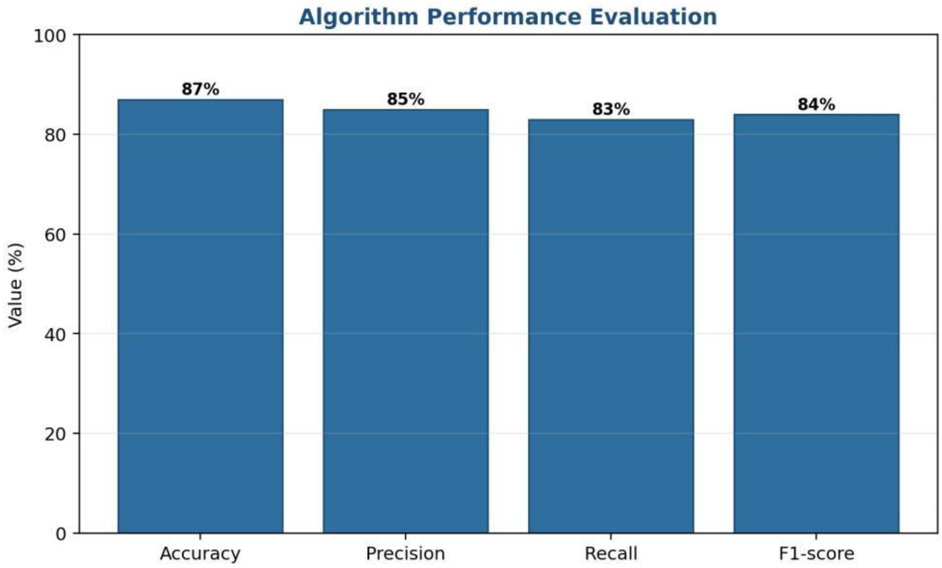

Figure 4. Algorithm performance metrics of the ABACAst predictive component.

The accuracy score suggests that the system correctly generated recommendations in most tested cases. The precision score indicates that most positive recommendations were relevant, while the recall score shows that the system identified a substantial proportion of relevant conditions. The F1-score confirms that the model maintained a balanced performance between precision and recall. Considering that ABACAst was designed for resource-constrained agricultural settings, these results support the practicality of lightweight predictive logic for farmer-oriented decision support.

ISO/IEC 25010 system evaluation

The system was also evaluated using ISO/IEC 25010 software quality characteristics. The evaluation covered functional suitability, performance efficiency, compatibility, usability, reliability, and security. The overall ISO/IEC 25010 summary average was 3.88 out of 5.00, equivalent to 77.5%, indicating a generally favorable system evaluation.

Software Quality Criterion	**Mean**	**Percentage**	**Interpretation**
Functional suitability	3.66	73%	Agree
Performance efficiency	3.90	78%	Strongly Agree
Compatibility	3.94	79%	Strongly Agree
Usability	3.92	78%	Strongly Agree
Reliability	3.92	78%	Strongly Agree
Security	3.96	79%	Strongly Agree
Overall summary average	**3.88**	**77.5%**	**Generally favorable / acceptable**

Table 2. Summary of ISO/IEC 25010 evaluation results including the overall average.

The ISO/IEC 25010 evaluation shows that ABACAst obtained an overall summary average of 3.88 or 77.5%, interpreted as generally favorable and acceptable. Among the evaluated criteria, security received the highest mean score of 3.96, indicating that users perceived the system as safe for storing and managing farm-related information. Compatibility, usability, and reliability also received strong ratings, suggesting that the system is accessible, easy to use, dependable, and suitable for daily farm decision-support activities. Although functional suitability received the lowest mean score of 3.66, it remained within the favorable range, indicating that the system generally met its intended functions but may still be improved through additional features and refinements.

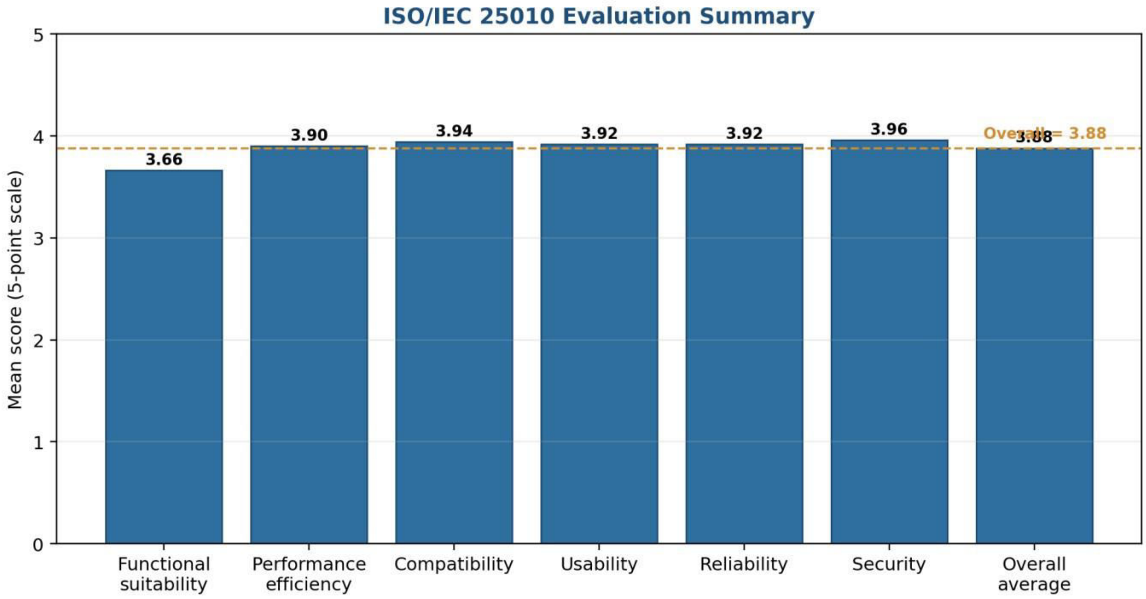

Figure 5. ISO/IEC 25010 evaluation results including the overall summary average.

Among the criteria, security obtained the highest mean score of 3.96, suggesting that users perceived ABACAst as a secure platform for entering and managing farm information. Compatibility followed with 3.94, indicating that the system performed well across browsers, devices, and operating environments. Usability and reliability both obtained 3.92, showing that users found the system easy to use and dependable. Performance efficiency obtained 3.90, suggesting that users perceived the system as responsive in processing requests and loading information. Functional suitability obtained 3.66, which remained favorable but also indicates that additional features and deeper domain-specific functions may further improve system usefulness.

Discussion of system contribution and limitations

The results demonstrate that ABACAst can support sustainable abaca production by organizing farm data, providing structured recommendations, and improving access to decision support.

Compared with manual farm record keeping and fragmented agricultural references, the system offers a more centralized and practical platform for farmers and local agricultural stakeholders. The system also supports the use of digital agriculture in smallholder environments where simplicity, interpretability, and usability are essential.

However, the system also has limitations. Its recommendation quality depends on the accuracy and completeness of farmer-provided data. Inaccurate disease reports, incomplete farm records, and limited historical data may affect prediction reliability. The system also does not yet integrate real-time climate data, soil sensors, or market analytics. Thus, ABACAst should be interpreted as a decisionsupport tool rather than a fully autonomous agricultural intelligence system. Future development should expand the dataset, improve disease recognition, and integrate climate-based analytics for more adaptive recommendations.

V. CONCLUSION

This study developed ABACAst, an AI-powered decision support framework for sustainable abaca production in Lanuza, Surigao del Sur. The system was designed to assist farmers in managing farm records, accessing cultivar information, monitoring disease-related concerns, and receiving rulebased recommendations for improved agricultural decision-making.

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The evaluation results indicate that ABACAst achieved satisfactory predictive performance, with 87% accuracy, 85% precision, 83% recall, and 84% F1-score. The ISO/IEC 25010 evaluation also showed a generally favorable overall average of 3.88/5.00, with particularly strong results in security, compatibility, usability, reliability, and performance efficiency. These findings demonstrate that ABACAst is functional, usable, secure, and potentially valuable as a localized decision-support platform for abaca farmers.

The study contributes to agricultural informatics by presenting a practical and interpretable decision-support framework for a specific high-value Philippine crop. It also provides a model for developing lightweight agricultural systems for resource-constrained farming communities. Future work should integrate larger datasets, climate-based forecasting, automated image-based disease detection, soil condition monitoring, and longitudinal evaluation to determine the long-term effect of ABACAst on farm productivity, sustainability, and farmer adoption.

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