Technological Innovation in Artisanal Agriculture: Comparison of Recommendation Approaches to Optimize Marketing

Innovación tecnológica en la Agricultura Artesanal: Comparación de enfoques de recomendación para optimizar la comercialización

DOI: https://doi.org/10.17981/cesta.06.01.2025.02

Review Article
Fecha de recepción: 03/15/2025, Fecha de aceptación:05/29/2025

Mary Elsy Arzuaga Ochoa
Universidad Nacional Abierta y a Distancia UNAD, Valledupar, Colombia
mary.arzuaga@unad.edu.co

Jean Carlos Baena Eljach
Universidad Nacional Abierta y a Distancia UNAD, Valledupar, Colombia
jean.baena@unad.edu.co

How to cite:
M. Arzuaga and J. Baena "Technological Innovation in Artisanal Agriculture: Comparison of Recommendation Approaches to Optimize Marketing". *J. Comput. Electron. Sci.: Theory Appl.*, vol. 6, no. 1, pp. 13-24, 2025. DOI: https://doi.org/10.17981/cesta.06.01.2025.02

Abstract
Introduction: Technological innovation has begun to significantly transform artisanal agriculture, especially in rural areas with limited access to information and communication technologies. In this context, recommender systems emerge as key tools to improve agricultural marketing processes by personalizing suggestions and strategies.
Objective: To compare and evaluate three recommended system approaches based on machine learning, collaborative filtering, and user segmentation to identify the most appropriate method to support agricultural marketing in rural areas with limited resources.
Method: A critical literature review was conducted to analyze the performance of the three recommender system approaches in terms of accuracy, applicability, and process optimization.
Results: Hybrid recommender systems, which integrate multiple approaches, demonstrated greater than 80% accuracy and greater adaptability to rural contexts. In contrast, while accurate, systems that rely on cloud computing present difficulties for implementation due to technological infrastructure requirements not available in many rural areas.
Conclusions: Recommender systems based on machine learning, collaborative filtering, and user segmentation offer viable solutions for optimizing agricultural marketing in rural settings. Their implementation contributes to the improvement of productivity and decision making, being an effective alternative to traditional methods. Hybrid models stand out for their flexibility and lower dependence on advanced infrastructure, which makes them a suitable option to support small-scale farmers.

Keywords: Agricultural commercialization; Collaborative filtering; Machine learning; Recommender systems; Rural areas

Resumen
Introducción: La innovación tecnológica ha comenzado a transformar significativamente la agricultura artesanal, especialmente en zonas rurales con acceso limitado a tecnologías de información y comunicación. En este contexto, los sistemas de recomendación emergen como herramientas clave para mejorar los procesos de comercialización agrícola mediante la personalización de sugerencias y estrategias.
Objetivo: Comparar y evaluar tres enfoques de sistemas de recomendación basados en aprendizaje automático, filtrado colaborativo y segmentación de usuarios con el fin de identificar el método más adecuado para apoyar la comercialización agrícola en zonas rurales con recursos limitados.
Método: Se realizó una revisión crítica de la literatura que analiza el desempeño de los tres enfoques de sistemas de recomendación en términos de precisión, aplicabilidad y optimización del proceso. La evaluación consideró estudios de implementación en contextos rurales, priorizando aquellos con limitaciones de infraestructura tecnológica.
Resultados: Los sistemas de recomendación híbridos, que integran múltiples enfoques, demostraron una precisión superior al 80%, además de mayor adaptabilidad a contextos rurales. En contraste, los sistemas que dependen de la computación en la nube, si bien son precisos, presentan dificultades para su implementación debido a requerimientos de infraestructura tecnológica no disponibles en muchas zonas rurales.
Conclusiones: Los sistemas de recomendación basados en aprendizaje automático, filtrado colaborativo y segmentación de usuarios ofrecen soluciones viables para optimizar la comercialización agrícola en entornos rurales. Su implementación contribuye a la mejora de la productividad y toma de decisiones, siendo una alternativa eficaz frente a métodos tradicionales. Los modelos híbridos destacan por su flexibilidad y menor dependencia de infraestructura avanzada, lo que los convierte en una opción adecuada para apoyar a los agricultores artesanales.

Palabras clave: Agricultura artesanal; Comercialización agrícola; Filtrado colaborativo; Machine learning; Sistemas de recomendación; Zonas rurales.

INTRODUCTION

In Colombia, artisanal farmers face significant barriers in marketing their products due to several variables that affect this process. According to Colombia's Ministry of Agriculture and Rural Development, the following are some of the main barriers for artisanal farmers in Colombia more than 70% of small producers depend on intermediaries to sell their crops, considerably reducing their profit margins [1]. Lack of access to modern marketing channels, technologies that connect farmers directly to markets, and effective distribution strategies limit their competitiveness. [2]. In addition, high logistics costs and the lack of adequate infrastructure increase post-harvest losses.

The problems above are amplified in the Department of Cesar. According to the Local Governance Observatory, 62% of farms in this region are family or artisanal, characterized by low levels of technification and limited access to larger markets. These conditions, dependence on intermediaries, and the lack of transportation and storage infrastructure increase logistics costs by 40% and contribute to a 3% annual drop in agricultural productivity. In addition, these barriers perpetuate economic inequalities and limit the sector's potential for sustainable development [1].

Machine Learning (ML) based recommendation systems have become highly relevant in several sectors, thanks to their ability to offer customized solutions that optimize processes and improve decision making [3]and it is also responsible for supplying raw materials for other industrial productions. Currently, the growth in agricultural production is not sufficient to keep up with the growing population, which may result in a food shortfall for the world's inhabitants. As a result, increasing food production is crucial for developing nations with limited land and resources. It is essential to select a suitable crop for a specific region to increase its production rate. Effective crop production forecasting in that area based on historical data, including environmental and cultivation areas, and crop production amount, is required. However, the data for such forecasting are not publicly available. As such, in this paper, we take a case study of a developing country, Bangladesh, whose economy relies on agriculture. We first gather and preprocess the data from the relevant research institutions of Bangladesh and then propose an ensemble machine learning approach, called K-nearest Neighbor Random Forest Ridge Regression (KRR. This ability to adapt and continuously improve can be instrumental in agriculture, where the conditions and needs of producers vary considerably, which can be a key factor in overcoming the barriers faced by farmers, as it can help them obtain more accurate and timely information on markets, prices, and consumption trends [4], [5], [6].

This scenario highlights the importance of exploring the use of technologies such as recommender systems, which could be key to improving logistics efficiency and expanding access to more profitable markets, contributing to the region's economic development [7].

This paper compares three approaches to developing recommended systems applied to the agricultural domain. The first paper proposes a system based on cloud computing and neural networks to recommend information about farm production and markets [8]. The second introduces a hybrid system that combines implicit collaborative filtering and sequential pattern analysis to improve the quality of recommendations in online shopping environments [9]. Finally, the work describes a hybrid system that fuses sequential rules and collaborative filtering to improve product recommendations in online marketplaces, with emphasis on customer segmentation [10].

Through this comparison, the recommendation methods, the technologies used and the results obtained will be analyzed in order to identify the strengths and limitations of each one in relation to the improvement of agricultural marketing processes, where farmers face barriers to access profitable markets [3], [11], [12].

METHODOLOGY

The methodology of this study focuses on a comparative analysis of three different approaches in the development of recommended systems applied to artisanal agriculture. Through a literature review and the formulation of hypotheses, we seek to evaluate the effectiveness of each system in terms of its applicability, accuracy, and ease of implementation in rural contexts [13]. This analysis will identify the strengths and limitations of each approach, thus contributing to understanding how recommended systems can improve the marketing of agricultural products in regions with limited resources. A sequence chart illustrating the key stages of the study is presented below. This diagram visualizes the methodological process followed, from the literature review to the formulation of conclusions, and helps to understand the flow and structure of the comparative analysis of recommender systems.

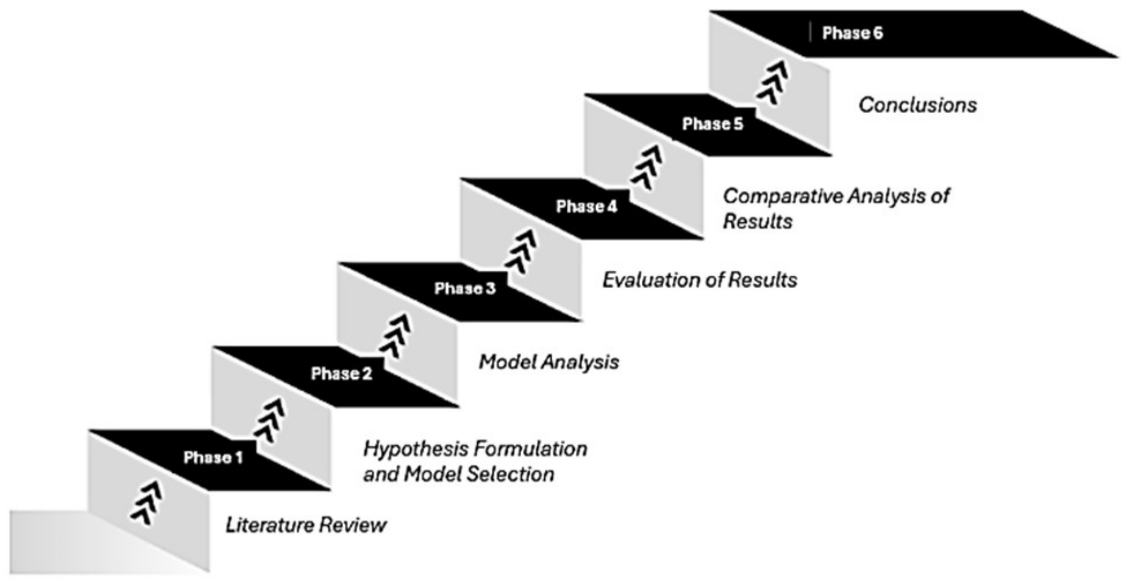

Fig. 1 Phases of the Study on Recommendation Systems in Agricultural Marketing

Figure 1 visualizes the study's phases, making it easy to follow the logical progression of the research. Each phase was crucial for evaluating and comparing the recommendation models, facilitating the interpretation of the obtained results.

Study design

This study is based on a comparative analysis of three articles on recommended systems applied to small-scale agriculture. The selected articles are [8], [9] and [10]. The objective is to evaluate the effectiveness of each approach in support of the stated hypotheses.

A. Hypothesis

The following hypotheses will guide the comparative analysis of the selected articles:

H1: Hybrid recommender systems provide more relevant and adapted recommendations to the context of smallholder agriculture compared to systems based solely on cloud computing and neural networks.

H2: Approaches based on collaborative filtering and sequential pattern analysis are more applicable in rural regions with limited infrastructure, as they can work with implicit data, while the system of [8] requires advanced technological infrastructure.

H3: Using customer segmentation and previous purchase patterns improves the personalization of recommendations for artisanal farmers, compared to a system that focuses on a more general recommendation based on a neural network.

B. Literature Review

An exhaustive literature review was carried out to analyze the methods, results, and conclusions of each selected article in depth. This review made it possible to identify the key characteristics of each recommendation system and their applicability in the context of small-scale agriculture.

C. Data Extraction

Specific criteria will be defined for the comparison of the items, which will include:

Accuracy of Recommendations: The effectiveness of the recommendations provided by each system was evaluated and expressed in terms of the percentage of hits [3], [14]. For example, a recent study evaluated a crop recommendation system based on deep learning, reporting an accuracy of 95.21% using Convolutional Neural Networks (CNN) [15].

Applicability in Rural Contexts: How each system adapts to infrastructure constraints in rural areas will be analyzed, considering the feasibility of implementation [16]. A report by the U.S. Government Accountability Office highlights that high upfront costs and a lack of uniform standards can hinder the adoption of precision agriculture technologies in rural areas [17].

Personalization of Recommendations: We examined how each article addresses segmentation of users and tailoring recommendations to their specific needs. Customization is key to tailoring recommendations to individual farmers' needs [18]. One study developed a recommender system that adjusts contact timing with farmers according to their observable characteristics, significantly increasing participation [19]. Likewise, [20] highlights the application of recommender and geolocation systems in tourism, underlining their potential to improve user safety and experience.

Ease of Implementation: The complexity of implementing each system will be considered, as well as the challenges mentioned by the authors in terms of technological resources and training [21]. Complexity in implementing recommended systems can be a significant barrier. Research indicates that the lack of standards and limited interoperability between agricultural technologies can complicate the integration of new systems [22]. However, the adoption of low-cost and open-source technologies, as in the case of the research on access control systems for COVID-19 detection, has led to the adoption of new technologies that can offer more affordable and scalable solutions for the implementation of agricultural recommender systems [23].

Results and Conclusions: The conclusions of each article will be compared about the hypotheses raised, identifying recommendations for implementing the systems in artisanal agriculture.

D. Qualitative Analysis

A qualitative analysis of the results of each article will be conducted to identify common themes and differences. This analysis will critically discuss how each article addresses the hypotheses and what evidence is presented to support or refute each.

E. Presentation of Results

The findings will be presented in a comparative table summarizing each article's key results about the defined criteria. In addition, a discussion will be included that synthesizes the strengths and weaknesses of each approach, as well as its relevance to the context of small-scale agriculture.

RESULTS

This section presents the results of the comparative analysis of the three recommendation systems applied to artisanal agriculture. The findings will be discussed in terms of the proposed hypotheses, the precision of the recommendations, the applicability in rural contexts, and the personalization of the suggestions.

A. Comparative Analysis

The system proposed is based on a cloud computing architecture and the combined use of BP (backpropagation) and SOM (Self-Organizing Maps) neural networks.[8], [24]. This approach allows handling large volumes of data and generating personalized recommendations from an explicit and implicit user model. The system's construction includes a user interest model and a hybrid algorithm that analyzes content and collaborative patterns. Such hybrid systems, which combine collaborative and content-based filtering using neural networks, have been shown to improve the accuracy of recommendations by integrating multiple sources of information [25]. Sin embargo, su efectividad está condicionada por el acceso a infraestructura tecnológica avanzada, como almacenamiento distribuido y procesamiento en la nube, lo cual puede limitar su implementación en zonas rurales [26], [27].

The system proposed by HOPE combines collaborative filtering techniques based on implicit scores and sequential pattern analysis. This hybrid approach does not rely on explicit user ratings, which is helpful in environments where detailed evaluations are not recorded [9].

The system calculates a predicted preference by combining results from collaborative filtering and sequential patterns, thus providing a more robust solution in the absence of explicit data [10], [28]. This type of hybrid model has demonstrated a significant improvement in the quality of recommendations by taking advantage of both temporal patterns and similarity between users based on observed behavior [29] [30] [31].

The hybrid approach, however, adds a layer of customer segmentation using the Recency, Frequency, Monetary (RFM) model. This segmentation allows users to be grouped according to their buying behavior, and sequential rules and collaborative filtering are applied within each group. Thanks to this segment-based personalization, the system achieves greater accuracy in recommendations and shows a high potential for applicability in agricultural contexts where it is possible to identify repetitive buying patterns among different farmer profiles [32], [33], [34].

The comparative analysis of the three recommendation approaches showed mixed results, with each system having its strengths and limitations in smallholder agriculture. Table 1 below summarizes the performance and applications of each system, which facilitates their analysis and understanding of their applicability in smallholder agriculture.

TABLE 1. COMPARISON OF RECOMMENDATION SYSTEMS. SOURCE: THE AUTHORS.

Characteristic	[8]	[9]	[10]
Method	Cloud + Neural Networks	CF implicit + sequential patterns	CF + rules + segmentation (RFM)
Main advantage	Processes large volumes of data	No explicit data required	High accuracy, adaptable to local context
Key limitation	Requires advanced infrastructure	Less accurate with little data	Requires purchase history
Accuracy (%)	76	74	>80
Applicability in small-scale agriculture	Low: limited by infrastructure	Medium: useful with basic data	High: ideal for segmentation of users

The table above shows that the three systems have different characteristics and results. The system stands out for its capacity to process large volumes of data, although its implementation is complex due to the need for advanced infrastructure [8]. On the other hand, the systems presented at [9] and [10] offers more accessible solutions, especially for rural regions with limited technological resources. However, the hybrid approach in [35] stands out for its high precision in recommendations and ability to better adapt to the reality of artisanal farmers.

B. Statistical Results

The results of evaluating the three recommended system approaches applied to marketing agricultural products show variations in accuracy, applicability, and adaptability to rural contexts. The system based on neural networks in the cloud achieved an accuracy of 76%, standing out for its capacity to handle large volumes of data, which makes it suitable for environments with large amounts of information. However, its main limitation is that it requires advanced infrastructure, making it challenging to implement in rural areas with limited technological resources. In contrast, the hybrid system combining implicit collaborative filtering and sequential pattern analysis showed an accuracy of 74%.

This system is most useful in contexts where explicit user data is not readily available, as it relies on implicit data. Despite being useful in such environments, its accuracy is slightly lower than that of the other approaches. Finally, the hybrid system using RFM segmentation and collaborative filtering achieved an accuracy above 80%, showing the best performance in personalizing recommendations. This approach allows a more precise adaptation to the needs of artisanal farmers thanks to user segmentation. However, its main limitation is that it requires a previous purchase history, which could be an obstacle in contexts where users have little historical information. Table 2 shows the importance of selecting the appropriate system according to available resources and environmental conditions.

TABLE 2. COMPARISON OF RESULTS. SOURCE: OWN ELABORATION

Approach	Accuracy	Advantages	Limitations
Cloud Computing + Neural Networks	76%	Handles large volumes of data	Requires advanced infrastructure
Collaborative Filtering + Sequential Patterns	74%	Useful with implicit data	Less accurate with little explicit data
Collaborative Filtering + RFM Segmentation	>80%	High customization	Requires purchase history

These results indicate that the cloud computing-based system is robustly accurate but is limited by infrastructure requirements. In contrast, hybrid systems, especially those incorporating RFM segmentation, are more effective for rural contexts due to their ability to adapt to local conditions and customize recommendations.

C. Key aspects of the results

Methodological approach and quality of recommendations

The system in [8] It is based on neural networks, specifically Convolutional Neural Networks (CNN) or Recurrent Neural Networks (RNN), which are widely used to process large volumes of data. This approach generates accurate recommendations but relies on advanced technological infrastructure (cloud computing). Although effective in well-resourced environments, it has a key limitation in rural areas due to a lack of access to advanced technological resources.

On the other hand, in [9] and [10] collaborative filtering and sequential pattern analysis are used to generate recommendations based on implicit data, such as user purchase behavior. These hybrid approaches are more accessible for rural areas because they require less advanced infrastructure and can operate with implicit data, facilitating their implementation in limited resources. In addition, recent studies have developed Hybrid Association Models (HAM) that combine long-term user preferences, sequential patterns and synergies between items, significantly improving the accuracy of recommendations [28].

Accessibility and adaptability in rural contexts

By relying on cloud computing, the system has the advantage of handling large volumes of data and providing accurate recommendations. However, its implementation is limited in rural areas with limited technological resources. Farmers in areas with poor infrastructure will not be able to take advantage of the full potential of this system without adequate connectivity and advanced computing resources [8].

In contrast, research shows greater adaptability to rural conditions. They can provide helpful recommendations by relying on implicit buying patterns and customer segmentation techniques, even in contexts where explicit data are not readily available. Their lower dependence on advanced infrastructure makes them more viable for farmers in resource-limited areas. Furthermore, in [29] proposes a cloud-enabled crop recommendation platform using machine learning algorithms for precision agriculture, demonstrating the feasibility of technological solutions adapted to rural contexts [9] y [10].

Evidence of efficacy and support for the hypotheses

The researchers reported 76% accuracy in recommendations, supporting the hypothesis that neural networks can generate highly accurate recommendations. However, this accuracy is accompanied by the limitation of advanced infrastructure. This system would be effective in urban settings or areas with high connectivity, but its applicability in rural areas is reduced due to the lack of technological resources [8].

For this part, [9] reports an accuracy of 74%, and [10] exceeds 80%. In this context, the results of [10] show how customer segmentation using RFM improves the personalization of recommendations and provides superior performance in terms of adaptability to different buying behaviors. Although these systems do not reach the same accuracy in absolute terms, their effectiveness and applicability in rural areas are considered higher. In addition, studies such as that of [30] have developed hybrid recommender systems using Long Short-Term

Memory Network (LSTM) and CNN, significantly improving recommendation accuracy by considering past preferences and product visual features.

Impact on agricultural commercialization

The analysis shows that [8] It is effective in terms of accuracy but presents challenges in its practical implementation in artisanal agriculture. The need for advanced infrastructure hinders its adoption in rural areas, limiting its direct impact on agricultural commercialization.

The systems of [9] and [10] are more accessible and present great potential for improving the commercialization of agricultural products in the context of artisanal farmers. Their flexibility to operate with limited data and their ability to adapt to different buying behaviors make these systems more suitable to address the challenges of artisanal agriculture in rural areas, where access to advanced technologies is restricted.

In line with this, [36] developed a hybrid recommendation system based on personal behavior pattern analysis, demonstrating the efficacy of combining traditional techniques with sequential pattern analysis to improve recommendation accuracy in data-limited settings.

Este análisis cualitativo ha permitido identificar no solo las ventajas de cada sistema, sino también las limitaciones que deben ser consideradas al implementar estos enfoques en el contexto agrícola. En última instancia, los sistemas híbridos, como los de [9] y [10], parecen ser los más adecuados para la agricultura artesanal, especialmente en regiones rurales con infraestructuras limitadas.

DISCUSIÓN

By comparing the three recommendation approaches, we can see their strengths and weaknesses, especially when applied to the context of artisanal agriculture. Each has advantages that can be useful in different situations, but limitations must be considered when implementing them in this sector. Below, we will break down what we found and how these findings apply to the reality of artisanal agriculture.

Systeme [8]: Cloud Computing and Neural Networks

This system is impressive in its ability to handle large amounts of data and provide very accurate recommendations. With an effective rate of 76%, it excels in personalization. However, there is one big hurdle: it needs an advanced technological infrastructure. This means that, for it to work well, it requires a stable internet connection and computing resources that are not always available in rural areas.

Studies such as that of [37] point out that although big data and cloud computing can transform agriculture, many rural communities do not yet have the conditions to adopt these technologies effectively. Similarly, [29] Acknowledge that cloud-based agricultural platforms can be beneficial, but require connectivity and suitable devices, which are not always guaranteed in the field. As in the military logistics sector, where technological tools improve efficiency in complex scenarios [38], recommender systems in agriculture can optimize marketing processes by integrating real-time data and providing customized solutions.

Therefore, although this system could be effective in urban areas or large cooperatives with access to these technologies, its implementation in rural areas would require several adjustments. Moreover, as indicated by [39], the cost-benefit ratio of these systems in rural contexts is usually unfavorable due to the high technical requirements.

Sistemas Híbridos de [9] y [10]

The systems proposed by [9] and [10] seem better designed for rural contexts. They are more flexible, operate with less data, and do not rely as much on sophisticated technologies. For example, the system of [9] depends on users' buying behavior without the need for them to give explicit ratings or comments. This is very useful in the field where detailed purchase records are often unavailable. This approach achieved an accuracy of 74%, which demonstrates its potential.

In addition, the system of [10] goes one step further by grouping farmers according to their purchase frequency, recent transactions, and how much they spend (RFM model). This allows for more personalized recommendations tailored to each type of farmer. This system achieved an accuracy of over 80%, which is relatively high considering that it does not require complex infrastructure.

Research such as that of [27] y [36] has shown that hybrid systems that combine different types of analysis, such as collaborative filtering and sequential patterns, can be more effective, especially when not much information about the users is available. It is also important to highlight the work of [40], who found that when recommendations are tailored to each farmer's profile, greater participation and better results are achieved in agricultural advisory programs.

In short, although the system of [8] presents a higher technical accuracy thanks to the use of neural networks and cloud computing, but its implementation in rural areas is impractical due to the high technological requirements. This makes its cost-benefit ratio in rural areas low, as also suggested by [39]. In contrast, the hybrid systems of [9] and [10] have not only been better suited to local conditions, but also offer a higher growth potential, as they can be scaled up and integrated with new data without the need for significant investments [41].

Finally, to achieve an effective and sustainable adoption of these tools, the support of local actors such as cooperatives, producer associations, and public entities is key, as they can accompany farmers in implementing, training, and monitoring these technological solutions.

AUTHOR CONTRIBUTIONS

Mary Elsy Arzuaga Ochoa: Manuscript writing, content development, article structuring, and preparation of figures and tables.

Jean Carlos Baena Eljach: Critical manuscript review, academic style editing, and validation of the methodological approach.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest regarding the content of this article.

CONCLUSIONS

This comparative study evaluated three approaches to recommender systems applied to artisanal agriculture, revealing that each has advantages and limitations depending on the context.

The system of [8], based on neural networks and cloud computing, stands out for its accuracy, but its implementation is costly and not very feasible in rural areas due to the lack of infrastructure. It is useful only in technologically advanced contexts.

The hybrid systems of [9] and [10], on the other hand, are better suited to rural realities. Their ability to operate with limited data, without requiring explicit ratings and using client segmentation, makes them ideal for regions with low connectivity or limited resources. In addition, their accuracy is competitive (74% and over 80%, respectively), and they have greater potential for scalability and customization.

In this context, hybrid approaches represent not only an effective technical solution, but also an economically and operationally viable alternative. For these tools to be adopted in a sustainable manner, the support of local institutions that facilitate their implementation, training and maintenance is essential.

FUTURE WORK

Although the results obtained are promising, further development of these systems is needed to overcome their limitations and expand their applicability. Some directions for future research include:

Optimization of recommendation algorithms: As the available data increases, recommender systems may benefit from more advanced algorithms, such as Convolutional Neural Networks or Optimization Models, that improve the accuracy and personalization of recommendations, especially in data-limited contexts.

Development of scalable versions for rural areas: Methods should be investigated to make recommended systems more scalable and accessible, using mobile platforms and low-cost cloud solutions that can be easily deployed in rural communities with limited technological infrastructure.

Integration of climate and agricultural data: To improve the accuracy of recommendations, it would be helpful to incorporate climate data and agricultural conditions into recommendation systems. This would allow farmers to make more informed decisions and anticipate market conditions.

Longitudinal impact assessment: To more effectively assess the impact of these systems, longitudinal studies that measure long-term outcomes in terms of profitability and market access for farmers would be beneficial.

Expansion to other crops: An interesting future line would be adapting the system to other agricultural crops, not just cassava, so that these systems can be used in a broader range of artisanal agriculture products.

With these research directions, it is hoped that more robust and accessible recommendation systems can be developed that not only optimize the marketing processes in small-scale agriculture but also contribute to the economic development of rural areas of the country [42] su factor común es la toma de decisiones y su posterior ejecución. Introducir las tecnologías de la información y la comunicación (TIC.

REFERENCIAS

[1] Ministerio de Agricultura y Desarrollo Rural, «MinAgricultura lanza Política Pública de Agricultura Campesina, Familiar y Comunitaria», 2018. [En línea]. Disponible en: https://www.minagricultura.gov.co/noticias/Paginas/MinAgricultura-lanza-Pol%C3%ADtica-P%C3%BAblica-de-Agricultura-Campesina,-Familiar-y-Comunitaria.aspx#:~:text=%C2%BFQu%C3%A9%20es%20la%20Agricultura%20Campesina,los%20territorios%20rurales%20del%20pa%C3%ADs.

[2] «Food and Agriculture Organization of the United Nations, "Digital Agriculture: Transforming Agricultural Supply Chains"». 2022. [En línea]. Disponible en: https://www.fao.org/agroinformatics/en

[3] M. Hasan et al., «Ensemble machine learning-based recommendation system for effective prediction of suitable agricultural crop cultivation», *Front. Plant Sci.*, vol. 14, p. 1234555, ago. 2023, doi: 10.3389/fpls.2023.1234555.

[4] M. Saban et al., «A Smart Agricultural System Based on PLC and a Cloud Computing Web Application Using LoRa and LoRaWan», *Sensors*, vol. 23, n.o 5, p. 2725, mar. 2023, doi: 10.3390/s23052725.

[5] *Gobierno del Cesar.* (2024), «Plan de Desarrollo Departamental 2024-2027». [En línea]. Disponible en: https://cesar.gov.co/d/index.php/es/menvertpolpla/menvertplandes/232-artmenplandes

[6] Organización de las Naciones Unidas para la Alimentación y la Agricultura, «Decenio de las naciones unidas para la agricultura familiar 2019-2028 Plan de acción mundial», 2019. [En línea]. Disponible en: https://www.familyfarmingcampaign.org/wp-content/uploads/2020/05/ca4672es.pdf

[7] G. E. R. Ibarra, «Agricultura de Precisión: La integración de las TIC en la producción Agrícola»», *Comput Electron Sci Theory Appl*, vol. 3, n.o 1, pp. 34-38, mar. 2022, doi: 10.17981/cesta.03.01.2022.04.

[8] H. Haiyan y C. Tao, «Design and Implementation of Agricultural Production and Market Information Recommendation System Based on Cloud Computing»», en en 2015 *8th International Conference on Intelligent Computation Technology and Automation (ICICTA, Nanchang, China: IEEE*, jun. 2015, pp. 367-370. doi: 10.1109/ICICTA.2015.99.

[9] K. Choi, D. Yoo, G. Kim, y Y. Suh, «A hybrid online-product recommendation system: Combining implicit rating-based collaborative filtering and sequential pattern analysis»», *Electron Commer Res Appl*, vol. 11, n.o 4, pp. 309-317, jul. 2012, doi: 10.1016/j.elerap.2012.02.004.

[10] D.-R. Liu, C.-H. Lai, y W.-J. Lee, «A hybrid of sequential rules and collaborative filtering for product recommendation»», *Inf Sci*, vol. 179, n.o 20, pp. 3505-3519, sep. 2009, doi: 10.1016/j.ins.2009.06.004.

[11] P. Rodriguez, A. Canon, y J. Orjuela-Castro, «Methodologies for characterization, evaluation, and improvement of logistics in the food supply chain», *Acta Logist*., vol. 10, n.o 2, pp. 175-190, jun. 2023, doi: 10.22306/al.v10i2.369.

[12] A. Derakhti, E. D. R. Santibanez Gonzalez, y A. Mardani, «Industry 4.0 and Beyond: A Review of the Literature on the Challenges and Barriers Facing the Agri-Food Supply Chain», *Sustainability*, vol. 15, n.o 6, p. 5078, mar. 2023, doi: 10.3390/su15065078.

[13] D. Tranfield, D. Denyer, y P. Smart, «Towards a Methodology for Developing Evidence-Informed Management Knowledge using Systematic Review», *Br. J. Manag*., vol. 14, n.o 3, pp. 207-222, sep. 2003, doi: 10.1111/1467-8551.00375.

[14] F. O. Isinkaye, M. O. Olusanya, y P. K. Singh, «Deep learning and content-based filtering techniques for improving plant disease identification and treatment recommendations: A comprehensive review», *Heliyon*, vol. 10, n.o 9, p. e29583, may 2024, doi: 10.1016/j.heliyon.2024.e29583.

[15] P. Naga Srinivasu, M. F. Ijaz, y M. Woźniak, «XAI-driven model for crop recommender system for use in precision agriculture», *Comput. Intell.*, vol. 40, n.o 1, p. e12629, feb. 2024, doi: 10.1111/coin.12629.

[16] A. A. Khan, M. Faheem, R. N. Bashir, C. Wechtaisong, y M. Z. Abbas, «Internet of Things (IoT) Assisted Context Aware Fertilizer Recommendation», *IEEE Access*, vol. 10, pp. 129505-129519, 2022, doi: 10.1109/ACCESS.2022.3228160.

[17] U.S. Government Accountability Office, «Precision Agriculture: Benefits and Challenges for Technology Adoption and Use», Washington, D.C., Informe gubernamental / Evaluación tecnológica GAO-24-105962, ene. 2024. [En línea]. Disponible en: https://www.gao.gov/products/gao-24-105962

[18] S. B. Dhal y D. Kar, «Transforming Agricultural Productivity with AI-Driven Forecasting: Innovations in Food Security and Supply Chain Optimization», *Forecasting*, vol. 6, n.o 4, pp. 925-951, oct. 2024, doi: 10.3390/forecast6040046.

[19] Susan Athey, Shawn Cole, Shanjukta Nath, Jessica Zhu, «Targeting, Personalization, and Engagement in an Agricultural Advisory Service», Harvard Business School, Cambridge, MA, Working Paper 24-006, ago. 2023. [En línea]. Disponible en: https://www.hbs.edu/ris/Publication%20Files/24-006_e1827b21-cdeb-4bd2-8537-3397e4c7fa8a.pdf

[20] Adalberto David Solano-Barliza, «Revisión conceptual de sistemas de recomendación y geolocalización aplicados a la seguridad turística», *CESTA: Computer and Electronic Sciences: Theory and Applications*, vol. 2, n.o 2, pp. 37--43, 2021.

[21] R. Astuti y L. Hidayati, «How might blockchain technology be used in the food supply chain? A systematic literature review», *Cogent Bus. Manag.*, vol. 10, n.o 2, p. 2246739, dic. 2023, doi: 10.1080/23311975.2023.2246739.

[22] M. Y. Shams, S. A. Gamel, y F. M. Talaat, «Enhancing crop recommendation systems with explainable artificial intelligence: a study on agricultural decision-making», *Neural Comput. Appl.*, vol. 36, n.o 11, pp. 5695-5714, abr. 2024, doi: 10.1007/s00521-023-09391-2.

[23] Y. T. Ternera Muñoz, «Sistema de Control de Acceso basado en Hardware y Software Libre para la Detección de potenciales infectados de COVID-19», *Comput. Electron. Sci. Theory Appl.*, vol. 2, n.o 2, pp. 9-20, dic. 2021, doi: 10.17981/cesta.02.02.2021.02.

[24] M. Uppal, D. Gupta, S. Juneja, G. Dhiman, y S. Kautish, «Cloud-Based Fault Prediction Using IoT in Office Automation for Improvisation of Health of Employees», *J. Healthc. Eng.*, vol. 2021, pp. 1-13, nov. 2021, doi: 10.1155/2021/8106467.

[25] Y. Huo, «Agricultural product E-commerce recommendation system based on neural factorization machine in smart cities»», *Internet Technol Lett*, vol. 4, n.o 1, p. 216, 2021, doi: 10.1002/itl2.216.

[26] Mudita y D. Gupta, «A Comprehensive Study of Recommender Systems for the Internet of Things», *J. Phys. Conf. Ser.*, vol. 1969, n.o 1, p. 012045, jul. 2021, doi: 10.1088/1742-6596/1969/1/012045.

[27] J. Bobadilla, F. Ortega, A. Hernando, y A. Gutiérrez, «Recommender systems survey»», *Knowl-Based Syst*, vol. 46, pp. 109-132, jul. 2013, doi: 10.1016/j.knosys.2013.03.012.

[28] B. Peng, Z. Ren, S. Parthasarathy, y X. Ning, «HAM: Hybrid Associations Models for Sequential Recommendation»». 2020. doi: 10.48550/ARXIV.2002.11890.

[29] N. N. Thilakarathne, M. S. A. Bakar, P. E. Abas, y H. Yassin, «A Cloud Enabled Crop Recommendation Platform for Machine Learning-Driven Precision Farming»», *Sensors*, vol. 22, n.o 16, p. 6299, 2022, doi: 10.3390/s22166299.

[30] H. Daneshvar y R. Ravanmehr, «A social hybrid recommendation system using LSTM and CNN»», *Concurr Comput Pr. Exp*, vol. 34, n.o 18, p. 7015, 2022, doi: 10.1002/cpe.7015.

[31] A. V. Shinde, D. D. Patil, y K. K. Tripathi, «A Comprehensive Survey on Recommender Systems Techniques and Challenges in Big Data Analytics with IOT Applications», *Rev. Gest. Soc. E Ambient.*, vol. 18, n.o 2, p. e05195, mar. 2024, doi: 10.24857/rgsa.v18n2-097.

[32] A. Bhola y P. Kumar, «ML-CSFR: A Unified Crop Selection and Fertilizer Recommendation Framework based on Machine Learning», *Scalable Comput. Pract. Exp.*, vol. 25, n.o 5, pp. 4111-4127, ago. 2024, doi: 10.12694/scpe.v25i5.2599.

[33] S. B. Kamatchi y R. Parvathi, «Improvement of Crop Production Using Recommender System by Weather Forecasts», *Procedia Comput. Sci.*, vol. 165, pp. 724-732, 2019, doi: 10.1016/j.procs.2020.01.023.

[34] J. Konaté, A. G. Diarra, S. O. Diarra, y A. Diallo, «SyrAgri: A Recommender System for Agriculture in Mali», *Information*, vol. 11, n.o 12, p. 561, nov. 2020, doi: 10.3390/info11120561.

[35] D.-R. Liu, C.-H. Lai, y W.-J. Lee, «A hybrid of sequential rules and collaborative filtering for product recommendation», *Inf. Sci.*, vol. 179, n.o 20, pp. 3505-3519, sep. 2009, doi: 10.1016/j.ins.2009.06.004.

[36] Z. Fang, L. Zhang, y K. Chen, doi: 10.48550/ARXIV.1607.02754.

[37] S. Wolfert, L. Ge, C. Verdouw, y M.-J. Bogaardt, «Big Data in Smart Farming – A review», *Agric. Syst.*, vol. 153, pp. 69-80, may 2017, doi: 10.1016/j.agsy.2017.01.023.

[38] A. R. Barrios Ulloa, «Comparación de modelos de propagación de ondas de radio de un canal inalámbrico en el área urbana de la ciudad de Barranquilla», *Comput. Electron. Sci. Theory Appl.*, vol. 2, n.o 1, pp. 31-38, jul. 2021, doi: 10.17981/cesta.02.01.2021.03.

[39] M. Y. Shams, S. A. Gamel, y F. M. Talaat, «Enhancing crop recommendation systems with explainable artificial intelligence: a study on agricultural decision-making»», *Neural Comput Appl*, vol. 36, n.o 11, pp. 5695-5714, 2024, doi: 10.1007/s00521-023-09391-2.

[40] S. Athey, S. Cole, S. Nath, y J. Zhu, «Targeting, Personalization, and Engagement in an Agricultural Advisory Service»». Harvard Business School, Cambridge, MA, 2023. [En línea]. Disponible en: https://www.hbs.edu/ris/Publication%20Files/24-006_e1827b21-cdeb-4bd2-8537-3397e4c7fa8a.pdf

[41] F. Ricci, L. Rokach, y B. Shapira, «Recommender Systems: Introduction and Challenges»», en en Recommender Systems Handbook, F. Ricci, L. Rokach, y B. Shapira, Eds., Boston, MA: Springer US, 2015, pp. 1-34. doi: 10.1007/978-1-4899-7637-6_1.

[42] G. E. Rambauth Ibarra, «Agricultura de Precisión: La integración de las TIC en la producción Agrícola», *Comput. Electron. Sci. Theory Appl.*, vol. 3, n.o 1, pp. 34-38, mar. 2022, doi: 10.17981/cesta.03.01.2022.04.

Author 1: has a bachelor's degree in mathematics and computer science, specializing in Technology Mediated Education and Pedagogy, and Orientation of Integral Vocational Training. She has a diploma in university teaching and a master's degree in pedagogy, and she is currently pursuing a doctorate in ICT. She has extensive experience as a teacher in elementary, middle, and higher education and has held academic leadership roles in

educational institutions. His work has focused on designing and implementing innovative pedagogical strategies that integrate emerging technologies to improve teaching and learning processes, emphasizing rural contexts and developing educational projects related to artisanal agriculture. https://orcid.org/0000-0003-1938-3411

Author 2: has a degree in Mathematics, is a specialist in Mathematics Education, and has a master's degree in Natural Sciences Education. He is currently pursuing a Doctorate in Educational Sciences. He has extensive experience in designing and implementing innovative teaching strategies to improve learning processes at different educational levels. Her work has focused on strengthening the teaching of exact and natural sciences, promoting active methodologies adapted to the needs of students. https://orcid.org/0000-0002-3521-4493