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Objective Evaluation of Mobile Applications for Small Farm Management in Albania with Fuzzy Methods

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Abstract: In the context of technological development and digitalization of agriculture, mobile applications are playing an increasingly essential role in the management of small farms located in countries with fragmented agricultural structures. The aim of this research is to evaluate the most widely adopted mobile applications for monitoring and managing agricultural activities in areas with high agricultural potential such as Myzeqe, Korça, and Saranda in Albania. In order to achieve an impartial and sustainable assessment, multi-criteria decision-making (MCDM) methods integrated with fuzzy logic helped address the uncertainties and subjectivity in the evaluation process. The fuzzy CRiteria Importance through Intercriteria Correlation (CRITIC) method was employed to objectively determine the weights of the criteria based on the variability and contradiction between them. The fuzzy Combined Compromise Solution (CoCoSo) method was then adopted to rank the mobile applications. As revealed from the findings in this study, the most highly-rated criteria by experts, i.e., criterion C1-Ease of use and criterion C6-Integration with other technologies had the highest weight. The least rated criterion by experts was criterion C7-Technical support and training. AgriApp (A7) was the mobile application identified with the best performance. The contribution of this research lied in the building of a structured and objective framework to evaluate mobile technologies applied in agriculture, thus enabling more informed decisions for their adoption at the local and regional level.

Keywords: Multi-criteria decision-making; Fuzzy CRiteria Importance through Intercriteria Correlation; Fuzzy Combined Compromise Solution; Agriculture; Mobile applications

1 Introduction

In recent decades, digital technologies have begun to play an indispensable role in agricultural development [1]. This development has particularly affected countries with small farms where a lack of resources and limited infrastructure have prevented the adoption of more efficient practices. Digitalization in agriculture is a great opportunity for detailed monitoring of activities and accurate management of resources such as water, fertilizers, and pesticides [2]. It offers a better connection of farmers with the market, agricultural advisors, and supporting institutions. Mobile technologies could increase efficiency in farm management and improve decision-making [3, 4]. However, the use of mobile applications and digital services by small farmers is often hindered by various factors such as economic environments, digital qualifications of farmers, inadequate technological and cultural infrastructure, and mismatch between local requirements and technological solutions [5].

In the Albanian context, agriculture is one of the main sectors of rural development, especially in areas with high agricultural potential such as Myzeqe, Korça, and Saranda. These areas are characterized by very promising climatic and soil conditions, but farmers often face numerous challenges such as land fragmentation, scarce financial resources, a lack of technological infrastructure, and a digital divide that limits the effective use of mobile applications that can alleviate these obstacles. This creates a need for studies that do not simply document the existence of applications, but evaluate them in an objective and contextual manner, taking into consideration technical, social, and economic factors. For this, the integration of multi-criteria decision-making methods (MCDM) with fuzzy logic have become effective tools in controlling the complexity and subjectivity in the evaluation of agricultural technologies and new technological applications. Concrete applications of fuzzy Analytic Hierarchy Process (AHP), Fuzzy Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) or other MCDM methods have been widely explored for technology selection, land selection, digital service adoption, etc. [6–9]. However, there are few studies that combined fuzzy CRiteria Importance through Intercriteria Correlation (CRITIC) and fuzzy Combined Compromise Solution (CoCoSo) methods in the agricultural context to analyze mobile applications based on technological, economic or social criteria. In this light, the main purpose of this research is to evaluate and rank mobile applications by using the Fuzzy CRITIC and Fuzzy CoCoSo methods for monitoring and managing agricultural activities in small farms with high agricultural potential in Albania.

Apart from the main objective, this research achieved the following specific goals:

•Selection of criteria for evaluating mobile applications from the perspective of smallholder farmers in Albania;

•Selection of experts who would evaluate mobile applications based on the defined criteria;

•Application of the Fuzzy CRITIC and Fuzzy CoCoSo methods to determine the weights of the criteria and rank mobile applications according to their relative performance;

•Analysis of the results to identify the main factors that influenced the adoption and effective use of mobile applications by smallholder farmers; and

•Recommendations for application developers, policymakers, and supporting organizations for the improvement and dissemination of these technologies in Albania.

This research contributed in the following ways: First, it provided an objective framework for evaluating mobile applications in the Albanian context, using a combination of modern fuzzy MCDM methods. Second, it identified and weighed key factors that influenced the adoption and performance of mobile applications for small farms. Third, it ranked the most widely used applications according to their performance, thus highlighting the more appropriate criteria or the aspects that need to be improved. Fourth, it provided practical recommendations for software developers, policymakers, and technology support institutions, so that mobile applications could become more accessible, better adapted, and have greater impact in practice.

The research also addressed these research gaps:

•The attempt to combine the Fuzzy CRITIC and Fuzzy CoCoSo methods in the evaluation of mobile applications for monitoring agricultural processes in the Albanian or regional context;

•A lack of empirical data from smallholder farmers in Albania on the real use, perception, and barriers to agricultural mobile applications;

•Evaluation criteria that often do not take into account of local aspects (e.g., language, internet infrastructure, digital skills of farmers, and technological culture) but focus more on technological or economic factors; and

•Mismatch between the offer of technological applications and the local needs of smallholder farmers in Albania.

In section two, the methodology applied for this study was discussed. In section three, the research results were given. In section four, a discussion of the results was made and the conclusions ended this research.

2 Methodology

The evaluation of mobile applications for monitoring agricultural processes in small farms in Albania included the following steps:

•First, identification and selection of criteria and mobile applications;

•Second, evaluation of mobile applications based on the selected criteria and the formation of a summary decision-making matrix; and

•Third, application of the fuzzy CRITIC and fuzzy CoCoSo methods.

The fuzzy CRITIC method was applied for weighing the criteria while the fuzzy CoCoSo method was applied for ranking the alternatives.

Based on the specific nature of this research, the first step of the methodology began with the careful selection of experts who would evaluate the mobile applications appropriately. Since farmers would be users of these mobile applications, it was considered reasonable that the experts be farmers themselves. Therefore, initially 15 farmers were selected; eight of them agreed to be evaluators of the mobile applications. The farmers who agreed to be part of the evaluation of the mobile applications had previous experience in managing mobile applications suitable for monitoring farms. Based on previous literature and with the help of these experts, the most important criteria were identified for the evaluation of mobile applications suitable for monitoring agricultural processes on small farms in Albania. The selected criteria are as follows:

•Ease of use (C1). This criterion addresses the simplicity of navigation and the use of functions by farmers [10–12].

•Functionality (C2). How complete the application is in covering farm activities such as irrigation, fertilization, planting, etc. [12, 13].

•Cost/accessibility (C3). This criterion has to do with the initial cost or the monthly or annual cost of the application [12, 14, 15].

•Language support (C4). One of the criteria is the language used in the application, whether or not the Albanian language is offered as an option [12, 16, 17].

•Offline work (C5). The application could operate in remote rural areas with limited Internet coverage [18, 19].
•Integration with other technologies (C6). The application can be connected to other possible applications or technologies, such as sensors, Global Positioning System (GPS), drones, and other IT systems on the farm [12, 20–22].
•Technical support and training (C7). This criterion determines whether the application provides technical assistance, user manuals, or training for users [12, 23–25].
•Data security (C8). How secure are user data and privacy protection [12, 26–28].

After the eight criteria above were selected, the next step was to select the mobile applications to be evaluated. From the suggestions of the experts and from a search in the "App store" and "Google", nine applications were selected; some of which were created specifically for farmers in Albania and the rest were international applications. The mobile applications that were evaluated in this research are as follows:
•AgroWeb (A1). Platform with agricultural information, recipes, and advice. Country of origin, Albania.
•AgroUdha (A2). Informative application for Albanian farmers. Country of origin, Albania.
•AgroTech Albania (A3). Provides training and access to technology for farmers. Country of origin, Albania.
•FarmLogs (A4). Farm management, activity monitoring, and production data. Country of origin, International.
•Cropwise Operations (A5). Satellite control, management of inputs and agricultural works. Country of origin, International.
•OneSoil (A6). Satellite monitoring and recommendations for agricultural land. Country of origin, International.
•AgriApp (A7). Agronomic information and farm management. Country of origin, International.
•eAgronom (A8). Input management and data reporting for small and large farms. Country of origin, International.
•AgroStar (A9). Focus on agricultural trade and advice for farmers. Country of origin, International.

The next step in this research was to create a decision-making model. Experts rated the selected mobile applications based on eight criteria, using linguistic values ranging from "Very bad" (VB) to "Very good" (VG) as shown in Table 1 [12, 29, 30].

Table 1. Linguistic values with the membership function

Linguistic Values	Fuzzy Numbers
Very Bad (VB)	(1, 1, 2)
Bad (B)	(1, 2, 4)
Medium Bad (MB)	(2, 4, 6)
Medium (M)	(3, 5, 7)
Medium Good (MG)	(5, 7, 9)
Good (G)	(7, 9, 10)
Very Good (VG)	(9, 10, 10)

The next step was to transform the linguistic variables into fuzzy numbers based on the membership function, in which the summary decision matrix was created [31, 32]. This matrix was formed by calculating the central values from the individual decision matrices provided by each expert [33, 34]. Once the summary decision matrix was formed, the steps of the fuzzy CRITIC and fuzzy CoCoSo methods were applied (Figure 1). The fuzzy CRITIC and fuzzy CoCoSo methods are well-known methods widely applied in real-life studies. Therefore, the following is a brief description of how these methods proceed. The first step of these methods is the normalization of the decision matrix [35, 36]. After the decision matrix is normalized, the steps of the fuzzy CRITIC method are performed to suitably determine the weights of the criteria [37, 38]. These weights are then used to calculate the S_i and P_i values in the fuzzy CoCoSo method [39]. The calculated S_i and P_i values are then used to perform the remaining steps of the fuzzy CoCoSo method, leading to the final ranking of the mobile applications [33, 40, 41]. he steps of the fuzzy CRITIC and fuzzy CoCoSo methods are given below [33].

The alternative identified with the highest value turned out to be the first alternative. After ranking the mobile applications based on expert ratings, validation by other fuzzy methods was performed to confirm the results. First, a comparative analysis was performed by comparing the results obtained by the fuzzy CoCoSo method with the results of several other fuzzy MCDM methods based on the weights of the criteria.

Then, sensitivity analysis was adopted to evaluate the impact of the criteria on the final ranking. This analysis included the creation of scenarios where the weights of the criteria were modified and the impact of the changes made on the final ranking was analyzed.

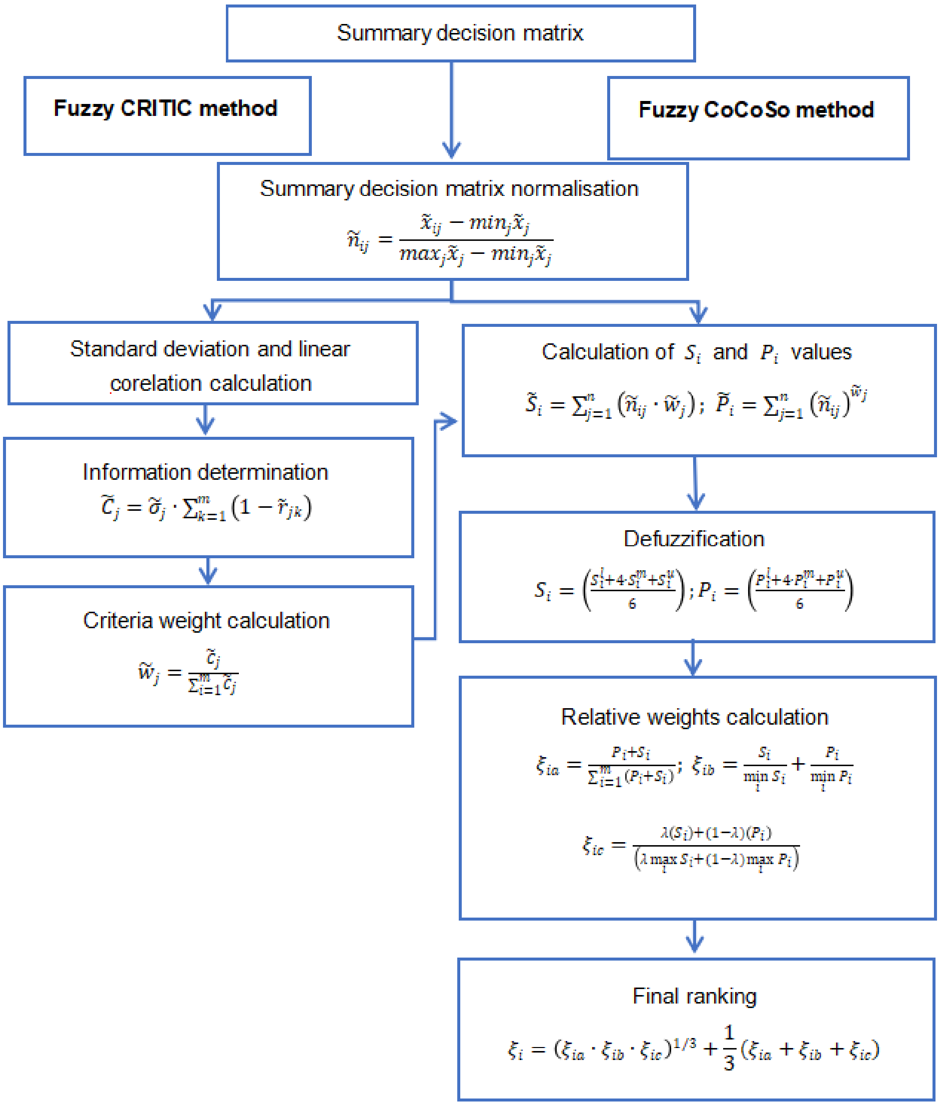

Figure 1. Fuzzy Criteria Importance through Intercriteria Correlation (CRITIC) and Combined Compromise Solution (CoCoSo) calculations

3 Results

To identify the selected mobile applications presented with the best characteristic in this research, the fuzzy CRITIC and fuzzy CoCoSo methods were used. To reduce subjectivity generated in the evaluation process by experts, the fuzzy CRITIC method was used. This method is suitable for calculating the weight of each criterion. After calculating the weights of the criteria with the fuzzy CRITIC method, the fuzzy CoCoSo method was applied to rank the mobile applications selected for this research. The results of these methods were dealt with below. Initially, the mobile applications were evaluated based on the selected criteria. The experts evaluated the mobile applications based on the linguistic values in Table 2. The linguistic evaluations of each mobile application by the experts were converted into fuzzy numbers, based on the membership function in Table 1, where each fuzzy number corresponded to a linguistic evaluation.

The next step of the methodology for this research was the average evaluation of the fuzzy numbers. In order to avoid bias in the evaluation, all experts were considered equally important. The average of the fuzzy numbers for all experts constituted the summary decision matrix. This matrix would be used for the application of the fuzzy CRITIC and fuzzy CoCoSo methods. Both methods have normalization of the decision matrix as the first step. The values of the normalization matrix should not exceed the value one (1). For example, if we are going to do the calculation for the first criterion and for the first alternative, the normalized value is as follows:

$n_{11} = \frac{5.25-2.25}{10.0-2.25} = 0.38; \frac{7.25-2.25}{10.0-2.25} = 0.65; \frac{9-2.25}{10.0-2.25} = 0.87$

The same method was applied to all normalized values of the decision matrix. After the decision matrix was calculated, the steps of the fuzzy CRITIC method were followed to determine the weights of the criteria.

First, in this method, the standard deviation was calculated. Then, the correlations between each pair of criteria were determined based on fuzzy numbers. After calculating the correlation between each pair of criteria, another matrix was formed where each correlation value was subtracted by one. In the newly formed matrix, the sums for each criterion were calculated. Finally, to determine the final weights of each criterion, the sum values for each criterion were multiplied by the standard deviation. The final weights of the criteria are presented in Table 3.

Table 2. Linguistic evaluations of the mobile applications by experts

E1	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**
A1	MG	G	G	MG	G	MG	G	VG
A2	MB	M	MG	MB	MG	M	MB	M
A3	MG	M	MG	MB	M	MG	MB	M
A4	G	VG	G	VG	G	VG	G	G
A5	G	MG	G	MG	MG	G	MG	G
A6	VG	G	VG	VG	VG	G	VG	G
A7	VG	VG	VG	VG	VG	VG	VG	VG
A8	MG	MG	G	MG	G	MG	G	MG
A9	MG	M	G	MG	G	M	MG	G
E8	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**
A1	MG	M	MG	MB	MG	M	MG	MG
A2	M	MB	MG	M	MB	MG	M	MB
A3	MG	M	MG	MB	MB	M	MG	MB
A4	MG	G	M	MG	G	MG	M	MG
A5	MG	MG	M	MG	M	M	MG	M
A6	MG	G	MG	VG	MG	G	MG	G
A7	G	MG	G	VG	G	MG	VG	G
A8	MG	M	MB	MB	MB	M	MG	MG
A9	M	M	M	M	MB	MG	M	MB

Table 3. Final weights of the criteria

Criteria	$\tilde{w}_j$
C1	(0.06, 0.15, 0.52)
C2	(0.06, 0.14, 0.28)
C3	(0.04, 0.11, 0.34)
C4	(0.04, 0.10, 0.27)
C5	(0.04, 0.12, 0.31)
C6	(0.06, 0.18, 0.47)
C7	(0.03, 0.10, 0.27)
C8	(0.04, 0.10, 0.24)

From the calculations of the fuzzy CRITIC method, it was noted that criterion C1-Ease of use and criterion C6-Integration with other technologies, were the criteria most valued by experts and had the greatest weight in the evaluation of mobile applications. The criterion least valued by experts was criterion C7-Technical support and training. The results of the fuzzy CRITIC method demonstrated that for farmers it was very important that a mobile application was easy to use and could integrate with other technologies. A mobile application becomes more flexible and usable when integrated with other technologies, e.g., drones and other technological devices, in the monitoring and treatment of farms. With the widespread implementation of the Internet, the criterion "technical support and training" for the use of mobile applications is no longer a problem for farmers who could now access any information.

After the criteria weights had been determined by the fuzzy CRITIC method, the fuzzy CoCoSo method was applied to rank the mobile applications. The steps of the fuzzy CRITIC method also served for the fuzzy CoCoSo method, where the first step for this method was the calculation of the P_i and S_i values. These values were calculated by weighing the normalized values with the criteria weights which were calculated with the fuzzy CRITIC method. Then, these values were multiplied by the corresponding fuzzy numbers. The next step of the fuzzy CoCoSo method continued with the scaling of the normalized values according to the criteria weights, where their defuzzification was then done. The calculation of the relative weights was the next step in the fuzzy CoCoSo method. Finally, based on the values of relative weights, the ranking of mobile applications was made in Table 4.

Table 4. Final ranking of mobile applications with the fuzzy Combined Compromise Solution (CoCoSo) method

MA	$\tilde{S}_i$	$\tilde{P}_i$	S_i	P_i	ξ_{ia}	ξ_{ib}	ξ_{ic}	ξ_i	Rank
A1	(0.11, 0.57, 2.17)	(0.61, 0.55, 0.55)	0.76	0.56	0.11	4.04	1.25	2.62	4
A2	(0.10, 0.30, 1.57)	(0.00, 0.30, 0.23)	0.46	0.24	0.06	2.00	0.31	1.11	9
A3	(0.04, 0.39, 1.79)	(0.40, 0.38, 0.33)	0.56	0.38	0.08	2.83	0.75	1.77	7
A4	(0.18, 0.75, 2.50)	(0.77, 0.75, 0.81)	0.95	0.77	0.15	5.32	0.79	2.93	3
A5	(0.08, 0.50, 2.07)	(0.56, 0.49, 0.49)	0.69	0.50	0.10	3.64	0.71	2.12	6
A6	(0.23, 0.87, 2.65)	(0.84, 0.87, 0.95)	1.06	0.88	0.16	6.03	1.22	3.53	2
A7	(0.27, 0.93, 2.70)	(0.89, 0.93, 1.00)	1.11	0.93	0.17	6.39	1.08	3.61	1
A8	(0.07, 0.47, 2.02)	(0.50, 0.46, 0.45)	0.66	0.46	0.09	3.39	1.03	2.19	5
A9	(0.03, 0.37, 1.77)	(0.00, 0.36, 0.31)	0.55	0.29	0.07	2.44	0.99	1.72	8

From the results of the fuzzy CoCoSo method, the three mobile applications that received the best ratings from the experts were A7, A6, and A4. The application that received the lowest rating based on the criteria considered in this research and the experts' rating was A2. The mobile application that ranked first was characterized by several criteria to render it the most preferred. This application was free and could perform without the Internet. Besides, this application could be integrated with other technologies, such as drones, to carry out various processes on the farm. Another criterion that characterized this application was data security. Farmers stored the data about their farms in the mobile applications and this could be a sensitive issue for them. The application that received the lowest rating from the experts did not meet some of the criteria required by farmers. This still suited the needs of some farmers, as they did not desire the integration of mobile applications with other technologies or considered offline operation of the applications problematic.

To verify the results of the fuzzy CoCoSo method, a comparative analysis was conducted using eight MCDM methods: fuzzy Ranking of Alternatives with Weights of Criterion (RAWEC), fuzzy Measurement Alternatives and Ranking according to the COmpromise Solution (MARCOS), fuzzy Weighted Aggregated Sum Product Assessment (WASPAS), fuzzy Simple Additive Weighting (SAW), fuzzy Multi-Attribute Border Approximation Area Comparison (MABAC), fuzzy Additive Ratio Assessment (ARAS), fuzzy Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), and fuzzy VIseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR).

From the calculations, the fuzzy CoCoSo method gave the same results as the other fuzzy MCDM methods though in some cases produced different rankings (see Figure 2). This change came in the order of the third, fifth, eighth, and ninth alternatives. Although there were some differences in the ranking of the alternatives, still the same mobile application was chosen first, since the first two applications had the same ranking in all other methods.

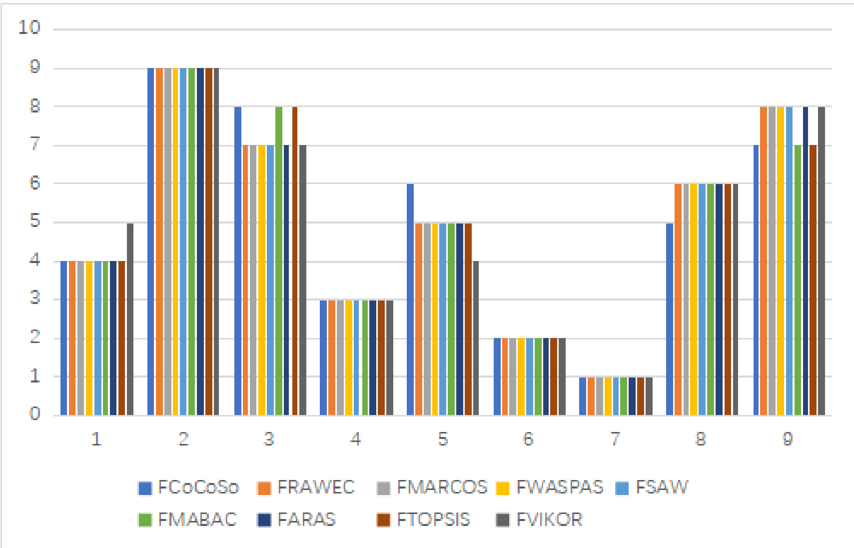

Figure 2. Comparative analysis of eight fuzzy multi-criteria decision-making methods

After confirming the fuzzy CoCoSo method for ranking the alternatives, a sensitivity analysis was performed to evaluate the degree of deviations when the weights of the criteria were modified. Therefore, a sensitivity analysis was performed by decreasing the importance of an individual criterion by 30%, 60%, and 90% as well as increasing the values of the other criteria proportionally. In this way, 24 scenarios were created. The purpose of this sensitivity analysis was to examine the impact of individual criteria on the final ranking of mobile applications. If the ranking was correct, the mobile application with a better value for that criterion would be ranked lower. The mobile application that was ranked higher had to improve that criterion which became worse.

From the results in Figure 3, there is a small difference in the ranking of the mobile application A7 and A8 as the A7 alternative only surpassed the A8 alternative in one scenario. In the other alternatives, there were no changes in the order of ranking; it was observed that the individual criterion did not have much impact on ranking.

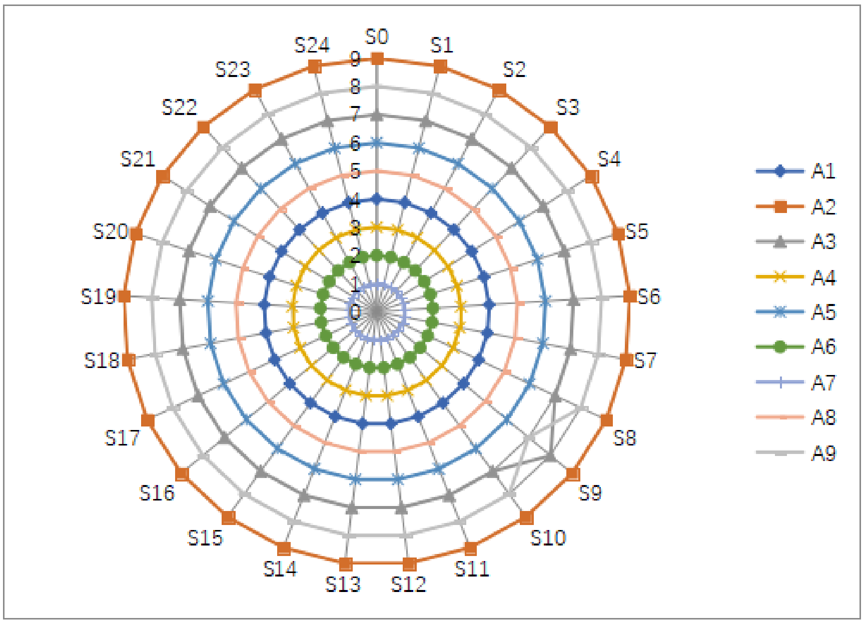

Figure 3. Results of the sensitivity analysis

4 Discussion

Mobile applications have been the most widely used technology in the agricultural sector in recent years as they occupy a crucial position in the digitalization and modernization of agricultural practices [42]. These applications are designed for use on mobile devices such as phones or tablets. Mobile applications emerge as a support for farmers in managing agricultural processes, such as planning of planting, weather forecasting, agricultural input management, pest and disease control, soil monitoring, access to markets and price information, and practical training [43, 44].

The adoption of mobile applications in the agricultural sector is particularly important in developing countries and rural areas, where the lack of infrastructure can be compensated by direct access to information and digital services. The use of such applications is a key factor in increasing efficiency and sustainability in agriculture by increasing production capacity and crop yield.

However, the rapid development of these technologies often has to face various challenges. Various factors such as the lack of content in local languages, the lack of stable Internet connection, the lack of user manuals for end users or the poor quality of some applications, have negatively affected the adoption and effectiveness of their use. In addition, the use of applications that have not yet been tested by a real in-depth analysis could cause significant harm to users. In practice, there are many mobile applications intended for use in agriculture. This diversity of applications creates the need for a structured and scientific evaluation so that end users, developers, and stakeholders engaged in public policies can make the necessary decisions on their adoption, support, and improvement. In this context, this research addressed the evaluation of mobile applications in monitoring agricultural processes through fuzzy decision-making methods. Fuzzy methods reduce uncertainty and subjectivity in the evaluation of these applications. Consequently, a fair evaluation of mobile applications constitutes an important step towards identifying the most appropriate solutions for sustainable and digitalized agricultural development.

In this research, the fuzzy CRITIC method was specifically applied in determining the weights of the criteria and the fuzzy CoCoSo method for ranking mobile applications. Eight experts participated in the evaluation of the criteria and mobile applications. Based on their experience and existing literature, the task of the experts was to identify the criteria for assessing the quality of these mobile applications. Then, the next task of the experts was to identify the mobile applications and evaluate them based on the selected criteria. The experts rated the mobile applications using linguistic variables ranging from "Very Bad" to "Very Good". These linguistic ratings were then converted into fuzzy numbers using the membership function. From the results, the most important criterion in the evaluation of mobile applications was criterion C1-Ease of use, followed by criterion C6-Integration with other technologies. The criterion least valued by the experts selected for this research was criterion C7-Technical support and training. It is very important for an application to be used easily since in many situations, the end users like farmers may have to encounter this difficulty during its implementation. It is also essential that the mobile application be easily integrated with other technologies such as drones, GPS systems, etc. Many processes on agricultural farms are interconnected. The least valued criterion, i.e., ease of use, confirmed one of the challenges that this type of technology has been facing.

The fuzzy CoCoSo method was used to rank mobile applications based on the defined criteria. This method combined with the fuzzy CRITIC method since both methods used the same normalization process [45, 46]. From the results of the fuzzy CoCoSo method, it was observed that the mobile application most highly rated by experts was A7, closely followed by A6, owing to their many similar characteristics. What is noticeable in these two applications is the ease of use and data security. Another characteristic of these applications is functionality. These applications offer many services in farm activities such as fertilization, irrigation, and planting. Furthermore, these two applications can serve as models for other applications since they demonstrate the most favorable characteristics for their users.

Based on the results of this research, it was noted that the implementation of a decision-making model based on qualitative criteria subjectively assessed by experts might differ if the same criteria and alternatives were used. Therefore, in this research, an attempt was made to reduce subjectivity in determining the importance of the criteria used for evaluating mobile applications [47]. Ultimately, the results of this research could help farmers choose the mobile application that suits their specific needs best, thus enabling them to improve their agricultural practices through smart agricultural technologies [12].

5 Conclusion

This research specifically addressed the evaluation of mobile applications suitable for monitoring agricultural processes in small farms in Albania, mainly in the Myzeqe, Korça and Saranda areas. For a more accurate and fair evaluation of mobile applications, a decision-making model based on the fuzzy CRITIC and fuzzy CoCoSo methods was applied. The fuzzy CRITIC method was applied to determine the weights of the criteria and the fuzzy CoCoSo method was applied to rank the mobile applications. For a comprehensive evaluation of the mobile applications selected for this research, the fuzzy MCDM methods enabled an objective and balanced analysis based on a series of technical and economic criteria. The findings of the fuzzy CRITIC method showed that the criterion with the highest impact in the evaluation of mobile applications was criterion C1-Ease of use, followed by criterion C6-Integration with other technologies, while criterion C7-Technical support and training obtained the lowest weight. The fuzzy CRITIC method allowed an objective determination of the weight of each criterion based on the variation and contradiction found between the assessments, in order to avoid subjective biases.

Furthermore, the findings from the fuzzy CoCoSo method showed that the A7 application offered the best result to serve as the optimal choice for farmers in these agricultural areas. To ensure that the methodology applied in this research provided a fair ranking of the applications, a comparative analysis as well as a sensitivity analysis were conducted to confirm the ranking of mobile applications.

Despite the important contributions to farmers, some limitations of this research should be taken into account:

•First, the number and types of applications evaluated may not represent all types of mobile applications used in the agricultural sector;

•Second, the criteria selected for this research focus on technical and economic ones but could be more inclusive for a perhaps more accurate evaluation of the applications; and

•Third, the involvement of more experts in the research constitutes another limitation. Also, the involvement of experts from countries with long-term experience in digitalized farms would be an advantage in the evaluation of these mobile applications.

Based on these limitations, the following are some possible suggestions for future research:

•First, the inclusion of additional criteria for evaluating the implementation of mobile applications in the decision-making process of other agricultural sectors;

•Second, the use of other fuzzy MCDM methods is another possibility for future research as the comparison of results produced by other methods can provide certainty for farmers in choosing these applications; and

•Third, in future research, it would be advantageous to include other existing applications as well as those that may appear in the future.

Ultimately, this research provided a valuable research model for the objective evaluation of mobile applications in the agricultural sector. It assisted in improving the decision-making process for the adoption of contemporary technologies and for the acceleration of digitalization in the agricultural sector. The model proposed in this research could serve as a basis for development policies and innovative projects that aim to increase efficiency and sustainability in the agricultural sector through mobile applications.

Data Availability

The data used to support the research findings are available from the corresponding author upon request.

Conflicts of Interest

The authors declare no conflicts of interest.

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