

EVALUATION OF TRACTORS BASED ON SUSTAINABILITY CRITERIA USING MULTI-CRITERIA DECISION-MAKING METHODS

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Abstract:

Selecting a tractor is one of the most complex investment decisions an agricultural producer faces. There are numerous types of tractors on the market, each differing in technical, economic, and ecological characteristics. The aim of this research is to demonstrate how multi-criteria analysis methods can aid in this decision-making process, using a practical example of selecting an optimal tractor for the Myzeqe area in Albania. In this study, a decision-making model was developed based on a hybrid fuzzy methodology, combining the fuzzy LOPCOW (Logarithmic Percentage Change-Driven Objective Weighting) and fuzzy MABAC (Multi-Attributive Border Approximation Area Comparison) methods. The findings show that the determination of criterion weights is less crucial, with the T15 tractor exhibiting the best overall indicators. This research primarily contributes to developing a methodology in agriculture that enhances production outcomes.

1 Introduction

Agricultural production is one of the most crucial sectors of the economy [1], which employs most of the rural population [2], and also contributes to the development of a country, as the gross national product (GNP) increases. This production faces numerous challenges related to modernization through the introduction of new types of mechanization [3]. However, tractors are still the most crucial agricultural machinery that is necessary for the improvement of that production [4]. They improve agricultural activities and reduce physical labor [5]. There are different types of tractors on the market, and choosing the right tractor is a complex task that involves taking into account numerous factors. These factors are different, of which technical, economic and environmental factors are the most crucial among them. Tractors are the most widely used machinery in agriculture [6]. This machinery requires a large investment, so it is important to choose which tractor to buy [7]. It is desirable that various attachments can be attached to the tractor, which will allow it to be used for various tasks in agriculture. By using mechanization, it is possible to cultivate a larger amount of land and increase yield and reduce labor costs [8]. When choosing a tractor, it is necessary to pay attention to the purposes for which they are used. If they are large farms, then it is necessary to purchase a tractor with greater power and stronger characteristics than when it comes to a small farm [9]. When choosing a tractor, it is necessary to take into account energy efficiency and that they should be environmentally friendly. Tractors form the basis of mechanization in agriculture, and with them it is possible to cultivate land, carry out sowing,

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harvesting and transport, as well as other activities that can be done with them [10]. The importance of tractors increases if agricultural holdings are small and fragmented, as is the case in developing countries such as Albania. In this paper, the focus is on the comparison of tractors used in agricultural production in Albania. In addition, the focus is on the technical characteristics of the tractor and on the economic and environmental criteria. In this way, efforts are being made to help improve agricultural production in Albania. In order to do this, a fuzzy approach will be used with appropriate methods, namely fuzzy LOPCOW (logarithmic percentage change-driven objective weighting) and fuzzy MABAC (Multi-Attributive Border Approximation Area Comparison). The fuzzy LOPCOW method will determine the importance of the used research criteria, while the fuzzy MABAC method will identify tractors that could best help in the improvement of agricultural production in Albania. Based on this, the specific goals of this research are set, namely:

- Identify key tractor criteria that include technical, economic and ecological aspects of agricultural production.
- Apply fuzzy LOPCOW and MABAC to evaluate the importance of criteria and rank tractors available on the Albanian market through the development of a hybrid methodology.
- Develop a decision-making model that will include criteria for evaluating tractors as well as selected tractors.
- Provide support through the development of a methodology that will enable decision-making on tractor selection.
- Investigate how certain tractors meet the set criteria.
- Give recommendations on which tractors give the best findings and thus help in the improvement of agricultural production in Albania.

Based on this, this paper focuses on the application of multi-criteria decision-making methods in order to achieve higher productivity, reduce costs and improve the sustainability of agricultural production in Albania.

1.1. Motivations and research gaps

The motivation of this research stems from the fact that agricultural production is of great importance in strengthening the economy of a country, so by improving agricultural production, a certain country develops. In order to do this, it is necessary to increase the use of mechanization in agricultural production in order to raise the technological level in agriculture. Mechanization is key to increasing productivity, reducing the required workforce, and increasing the competitiveness of small and medium-sized farms in particular. These farms are the most represented in agricultural production in Albania. That is why it is necessary to compare the tractors that are present in the territory of Albania using different criteria that take into account technical characteristics, economic and environmental factors that must be taken into account. Based on that, the motivation of this paper is as follows:

- To support agricultural producers by providing guidelines for the selection of tractors through the development of a decision-making model that will help farmers to make more efficient decisions and improve productivity in decision-making.
- Work on the improvement of mechanization in such a way that technology in agricultural production will be strengthened, which will help to improve agricultural production through increasing the effectiveness and efficiency of production.
- Develop sustainable agriculture that will take into account the resources available to Albania in order to preserve them, and this is not possible without the implementation of measures of sustainability and preservation of the environment.
- Help in the development of investments in agriculture through the development of a structured decision-making model that can help not only farmers but also the makers of agrarian policy measures in Albania to make the right decisions about the mechanization of agriculture.

The research gaps that this research solves are reflected in the following:

- The lack of a decision-making model in agriculture that includes the use of multi-criteria decision-making methods (MCDM), especially the combination of fuzzy LOPCOW and fuzzy MABAC methods in agriculture as well as in other sectors of the economy is little used in practice.

- Agricultural research in Albania was focused on global and regional levels, while a smaller focus was on the development of small and medium-sized farms, on the development of technology in agriculture. In particular, research on agricultural mechanization in Albania was not used.
- Fuzzy LOPCOW and fuzzy MABAC methods are not so prevalent in agricultural research, especially the LOPCOW method, since it is a newer MCDM method, so it is not widely promoted in these researches.

1.2. Novelties and contributions of the work

During the implementation of this research, certain novelties were introduced, which are reflected in the following:

- Application of the fuzzy LOPCOW and fuzzy MABAC methods in the comparison of tractors in agricultural production in Albania, where the fuzzy LOPCOW method is used to determine the importance of criteria, while the fuzzy MABAC method is used in the ranking and selection of the best alternatives regarding the choice of tractors. The combination of these methods offers new possibilities when connecting methods that use the same normalization.
- Focusing this research on technical, economic and ecological criteria, which includes the aspect of sustainability and ecology. In this way, the choice of tractor includes not only increasing productivity, but also reducing the negative impact on the environment through the preservation of the resources available to Albania.
- The development of agriculture in Albania focused on small and medium-sized farms and the improvement and modernization of agricultural mechanization in order to make this production productive and less labor-intensive.

Based on all of this, the contribution of this research is reflected in the following:

- Development of a decision-making model based on the use of technical, economic and ecological criteria, which provides an efficient approach to the evaluation and selection of agricultural tractors not only for agricultural producers but also for decision-makers on the development of agricultural production in Albania and in other countries.
- Providing practical guidance for farmers and decision makers and recommendations on which tractors to use in order to improve agricultural production in Albania and to develop national policies to subsidize future tractor purchases and mechanization programs.
- Integration of fuzzy methods into a unique hybrid methodology that enables the reduction of the steps of these methods because the same initial steps are used in the fuzzy LOPCOW and fuzzy MABAC methods, so they do not have to be calculated twice, which enables the development of other hybrid methodologies of fuzzy methods.
- Improvement of agricultural production in Albania based on the principles of sustainability and the application of ecological standards in order to reduce the impact of agriculture on the environment.
- Development of tools for future research based on the use of integrated fuzzy methods for the development of agricultural production.

1.3. Organizations of the paper

In addition to the introduction, this research consists of five more selections. In the second selection, an overview of the research is given, focused on the selection of tractors as the most crucial segment of agricultural mechanization. The third selection is focused on the development of research methodology based on the application of fuzzy methods. In the fourth selection, the methodology is applied on a practical example of tractor selection. The fifth selection is responsible for explaining the research findings through their discussions and giving the most crucial research findings as well as the limits and limitations of this research as well as guidelines for future research.

2 Literature review

During the review of the literature, first the papers that have researched the application of tractors in agriculture will be elaborated, and then the papers that have used MCDM methods in the selection of tractors

will be presented. Mainly in developing countries where small plots are prevalent, agricultural activities are carried out using small two-wheel tractors or otherwise known as tillers [11], as these types of tractors have a low acquisition cost [12]. However, the use of these tractors is often dangerous, especially in the trailer system during turns, as well as the difficulty in driving them [13]. This makes four-wheeled tractors more advantageous, but often these tractors also present their own problems, as they affect the compaction of the soil by the wide wheels [14]. To mitigate the phenomenon of soil compaction, it was estimated that one of the methods for this purpose is the use of ultra-narrow wheels [15]. The trend of recent years is the production of electric vehicles. This trend has also affected manufacturers of agricultural tractors, but some limitations such as battery life and long recharging periods make it possible for this technology not to gain much practical use, since the purchase of such a tractor constitutes a significant financial investment for the farmer and therefore this investment significantly affects the farmer's economy [16]. Fargnoli & Lombardi [17] conducted a review of the literature in the period 2009 - 2019 for the safety of agricultural tractors. They take into consideration some main criteria regarding the safety of agricultural tractors and the safety of the farmer's life. Efremov et al. [18] applied on a fleet of tractors an algorithm for optimizing their use in an agricultural enterprise. Bacenetti et al. [19] compared EGR (Exhaust Gas Recirculation) and SRC (Selective Catalytic Reduction) tractors regarding their impact on the environment during plowing. They came to the conclusion that the SRC tractor was better than the EGR tractor. Mattetti et al. [20] analyzed 44 tractors for loads in transmissions with integrated sensors proposing a suitable methodology. Kim et al. [21] analyzed the effects of soil depth and gear selection on the mechanical load and fuel efficiency of an agricultural tractor during plowing. Durczak et al. [22] compared empirical data and generated data, for the reliability of tractors in agricultural farms. Sunusi et al. [23] studied the traction control process in smart tractors. Yang et al. [24] used the genetic algorithm in the extrapolation of the load spectrum of the traction resistance of the tractor and the compilation of the load spectrum based on the selection of the optimal threshold. Mishra & Satapathy [25] surveyed 144 farmers and assessed their knowledge of agricultural machinery maintenance activities.

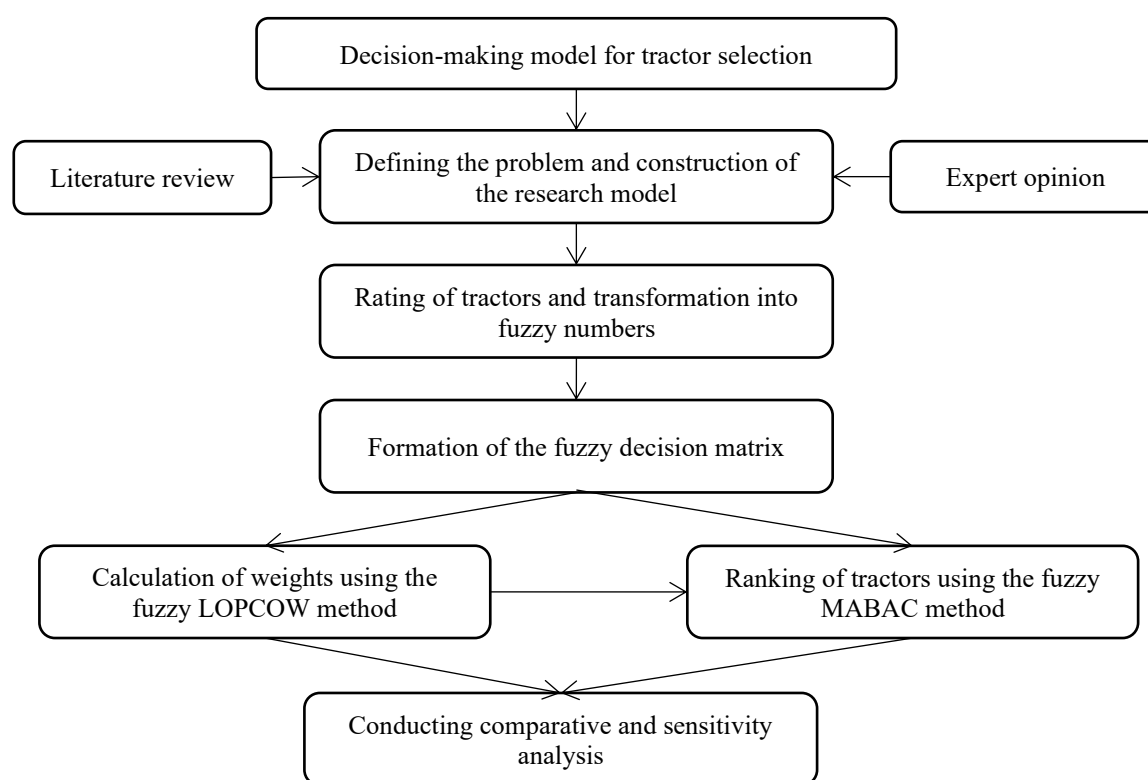
They found that 93.75% of the farmers sought help for the maintenance of the machines. Atlı [26] applied the fuzzy AHP (Analytic Hierarchy Process) method for the study of criteria that are crucial for the maintenance of agricultural machinery. Their damages make it possible for the agricultural activity to be interrupted and as a result the farmer may have a significant economic loss. Puška et al. [27] applied five MCDM methods for determining the weight of the criteria in the framework of the evaluation of heavy tractors used in agricultural production in Bosnia and Herzegovina. They also applied the CRADIS (compromise ranking of alternatives from distance to ideal solution) method for a ranking of tractors. García-Alcaraz et al. [28] applied a hybrid AHP-TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) approach to the identification of some attributes for the evaluation of agricultural tractors. They took into consideration 18 attributes and distributed the survey to farmers and sellers of agricultural machinery. Amini & Asoodar [29] applied the AHP method in selecting a tractor for rural areas in Ghaemshahr and Ahvaz cities of Iran. They selected 15 tractors at random and found that in the choice of a tractor, maintenance affects the amount of 49.4%. Puška et al. [16] applied a hybrid decision-making methodology with multiple criteria in selecting an optimal tractor. They examined five models of tractors and found that the Solis S 26 was the best model. For this, they applied the Logarithm Methodology of Additive Weights (LMAW) method to evaluate the importance of the criteria and then applied the Simple Additive Weighting (SAW) method to identify and rank the optimal tractor. Durczak & Selech [30] from the study they did on reliability and the basic parameters for buying a suitable tractor noticed that the Massey Ferguson tractor was the best in terms of reliability.

The result achieved corresponded to the sales that this tractor model had in Europe, mainly in Lithuania, Norway and Sweden. Rauniyar & Tamang [31] presented a ranking of agricultural tractors based on the attributes preferred by farmers. From the survey of 85 farmers, it was found that fuel consumption, horse power and a branded tractor with a low price were some of the main attributes they prefer. Reis et al. [32] built a multi-criteria model to evaluate tractors by family farmers. They based the construction of the model on three phases: the structuring phase, the evaluation phase and the recommendation phase. From the findings obtained, they emphasized that the best model was the tractor with a nominal power of 14.7 kW and this tractor was purchased by 53.3% of local families. Dettù et al. [33] studied the three main performance indicators in a tractor in the evaluation of driving style for agricultural tractors. Przywara et al. [34] studied the changes in the tractor market during the period 2010 to 2020 in Poland. Over 144,000 tractors were registered in Poland during these years. They found that the New Holland brand was the most registered, while the Kubota brand

with power up to 50kW was the best-selling brand. For power 50-140 kW, the New Holland brand dominated and >140 kW, the John Deere brand dominated.

3 Research methodology

The selection of tractors in Albania, specifically in the Myzeqe area, was made on the basis of the steps defined by this research (Figure 1). First, the experts who will participate in this research were selected. Four tractor salesmen and four professors from the University of Agriculture in Tirana were taken as experts in this research. They were taken for the following reasons, firstly, tractor sellers are familiar with the characteristics of the tractors they sell, and then they are also familiar with what customers or agricultural producers are looking for. In this way, they have information about tractors and customer wishes. Secondly, agricultural mechanization experts, i.e. professors, know based on their expertise what agricultural producers need in order to have the best effects from tractors in their production. After the experts were determined, they determined which criteria would be used and which tractors would be evaluated based on their knowledge and review of previous research, and based on this, a decision-making model was created. This decision-making model was made in the form of a decision-making matrix where the selected 17 tractors were observed with 11 criteria. For the sake of protection and possible problems, the real names of the tractors already marked from T1 to T17 will not be used, because it is not possible for all tractors to be the best, so a certain tractor should take the last place.



Figures 1. Research methodology.

In accordance with the objective of the research, the criteria for this research were selected. The criteria were set to reflect technical, economic and ecological aspects. However, the emphasis was on the technical aspects. In this way, the criteria are used to examine different dimensions when making decisions about choosing the most suitable strap. These criteria are as follows:

- Engine power (C1) determines the tractor's ability to perform heavy agricultural tasks, such as plowing and pulling heavy equipment [24; 28; 29]. Greater power enables greater efficiency on large surfaces or in demanding conditions.
- Fuel consumption (C2) directly affects long-term operating costs [27; 16]. Tractors with lower fuel consumption enable lower operating costs and greater economy in daily use.

- Maneuverability (C3) is crucial especially on smaller farms or in tight spaces [28]. The tractor's ability to move over varied terrain and avoid obstacles increases work efficiency.
- The size of the tractor (C4) depends on the size of the agricultural land and the type of work to be performed [24; 28]. Smaller tractors are suitable for smaller farms and jobs that require precision, while larger tractors are needed for more difficult and demanding tasks.
- Connecting equipment (C5) significantly increase tractor flexibility and farm value [25]. More attachment options allow greater versatility in use, making the tractor more useful for different tasks.
- Maintenance costs (C6) are key to long-term tractor management, as they reduce overall operating costs [27; 28; 29]. Frequent repairs and replacement of parts can negatively affect productivity and profitability.
- Environmental acceptability (C7) refers to meeting environmental standards, such as reduced emissions and reduced fuel consumption [16]. Environmental acceptability models not only reduce the impact on the environment, but also help users to meet increasingly strict legal regulations.
- Procurement costs (C8) are a significant factor when choosing a tractor, but it is necessary to link the price with long-term values, such as quality and maintenance [27; 28; 29]. Cheaper models may save money initially, but may require more investment in repairs in the long run.
- Driving comfort (C9) can significantly improve working conditions, especially for long-term tasks [25; 16]. Seat ergonomics, ease of handling and visibility increase productivity and reduce farmer fatigue.
- Carrying capacity and towing (C10) refers to the tractor's ability to carry and tow heavy loads, such as trailers and farm equipment, without compromising performance [24; 28]. Carrying capacity and traction directly affect the efficiency of performing various tasks.
- Purchase costs (C11) represent the total financial investment, which includes not only the basic price, but also additional fees such as taxes, insurance and accessories [27; 28; 29]. It is good to take into account all potential hidden costs in order to properly plan the budget.

In order to evaluate the selected tractors according to these criteria, a linguistic value scale ranging from very bad to very good with seven levels will be used [35-37]. Then these linguistic value scales are transformed into fuzzy numbers using the membership function, which determines which fuzzy number the linguistic value will be transformed into. By applying this value scale, all criteria should be as good as possible and maximized. In this way, the work of the experts is made easier because they do not have to think about what type of criterion it is. The next step in this methodology is the formation of a summary decision matrix, which is the initial step for any MCDM method. The formation of this matrix is done in such a way that the average values of the fuzzy numbers are found. By applying this principle, each expert is assigned the same importance and has the same influence on the final decision. Then, selected MCDM methods are used to determine the weight of the criteria and to determine the ranking of the tractors. Determining the weight of the criteria is done using the fuzzy LOPCOW method, which serves to objectively calculate the importance of the criteria based on the ratings of individual tractors according to the observed criteria. Thus, the same initial decision matrix is used for both of these methods. Ranking of tractors is done using the fuzzy MABAC method. In this research, these two methods will be combined into a unique hybrid method that has the following steps:

Step 1. Evaluation of tractors according to defined criteria and formation of a decision matrix

Step 2. Normalization of the summary decision matrix:

$$\tilde{r}_{ij} = \left(\frac{x_{ij}^l - x_{i \min}^l}{x_{i \max}^n - x_{i \min}^l}; \frac{x_{ij}^m - x_{i \min}^l}{x_{i \max}^n - x_{i \min}^l}; \frac{x_{ij}^n - x_{i \min}^l}{x_{i \max}^n - x_{i \min}^l} \right) \quad (1)$$

Where l is the first fuzzy number, m is the second fuzzy number and n is the third fuzzy number.

The weights are then calculated using the steps of the fuzzy LOPCOW method.

Step 3. Calculation of percentage (PV) for each criterion.

$$\widetilde{PV}_{ij} = \left| \ln \left(\frac{\sqrt{(\sum_{i=1}^m r_{ij}^2)/m}}{\sigma} \right) \cdot 100 \right| \quad (2)$$

Step 4. Weight calculation

$$\widetilde{w}_j = \frac{\widetilde{PV}_{ij}}{\sum_{i=1}^n \widetilde{PV}_{ij}} \quad (3)$$

After the criteria weights have been calculated, the steps of the fuzzy MABAC method continue, namely:

Step 5 Weighting of the normalized decision matrix with criteria weights (w_i) obtained by the steps of the LOPCOW method.

$$\widetilde{v}_{ij} = \widetilde{w}_i \cdot \widetilde{r}_{ij} + \widetilde{w}_i \quad (4)$$

Step 6 Determination of the boundary area matrix (G).

$$g = \left(\prod_{j=1}^m \widetilde{v}_{ij} \right)^{1/m} \quad (5)$$

Step 7 Calculation of the distance of alternatives from the border area.

$$\widetilde{Q} = \widetilde{V} - \widetilde{G} \quad (6)$$

Step 8 Calculation of the value of the MABAC method.

$$\widetilde{S}_i = \sum_{j=1}^n \widetilde{Q}_{ij}, \quad j = 1, 2, \dots, n, i = 1, 2, \dots, m \quad (7)$$

Step 9 Determining the final value by defuzzification of fuzzy numbers.

$$S = \frac{t_1 + 4t_2 + t_3}{6} \quad (8)$$

In this way, the first two steps are used, which are the same in both methods. After that, a comparative analysis is done, where the findings obtained by the fuzzy MABAC method are compared with other fuzzy methods, and a sensitivity analysis is carried out, where it is observed what happens to the ranking of tractors if the importance of the criteria changes.

4 Results

In order to determine which tractor gives the best findings, the rating of the tractor according to the selected criteria is used, and based on this rating, the weight of the criteria is first determined and the ranking list of tractors is formed. The experts' ratings are in the form of linguistic values (table 1). In order to represent these ratings, linguistic values will be assigned numerical labels. As follows: very bad – 1, bad – 2, medium bad – 3, medium – 4, medium good – 5, good – 6, very good – 7.

Table 1. Rating of tractors using linguistic values.

Expert 1	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
T1	5	5	6	6	6	6	6	4	6	6	6
T2	5	6	4	5	5	6	5	5	5	5	5
T3	4	6	4	6	5	6	6	5	6	5	5
T4	5	6	5	5	6	6	6	4	5	5	5
T5	5	7	5	6	5	5	7	5	6	4	5
T6	4	6	4	6	5	4	6	6	5	4	5
T7	4	7	5	6	5	5	5	6	4	4	5
T8	5	6	4	5	5	4	6	6	5	4	4
T9	5	7	4	6	5	5	5	6	4	5	5
T10	5	7	5	6	5	4	4	6	5	4	6
T11	5	7	4	6	5	5	6	6	4	5	4
T12	4	6	5	6	5	6	5	5	5	4	5
T13	5	7	5	5	5	5	6	5	4	4	6
T14	4	7	4	5	5	6	5	5	5	5	6
T15	6	4	5	5	7	7	6	4	7	7	3
T16	5	6	7	5	5	6	6	4	5	5	5
T17	5	7	4	4	5	6	5	6	4	5	6
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
Expert 8	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
T1	6	7	6	7	6	7	7	6	6	7	6
T2	6	5	6	6	6	6	5	6	5	6	5
T3	6	6	5	6	6	6	6	6	7	6	6
T4	7	6	7	6	6	7	6	7	6	6	5
T5	5	5	6	5	5	4	5	6	6	6	5
T6	5	6	6	6	6	5	6	5	5	5	5
T7	5	5	6	5	6	6	5	6	6	6	5
T8	5	6	5	4	6	5	4	5	5	5	4
T9	6	5	5	6	5	4	5	6	6	6	5
T10	5	6	6	5	6	5	5	5	6	5	4
T11	6	5	5	6	6	6	5	6	6	6	4
T12	5	6	6	5	6	4	5	5	6	5	5
T13	5	5	6	6	6	5	5	6	6	6	4
T14	6	5	6	5	6	6	6	5	5	5	5
T15	7	7	7	6	6	7	6	7	6	7	6
T16	7	5	6	5	6	5	6	5	6	5	4
T17	4	5	4	5	4	5	4	6	5	5	4

After the evaluations by the experts have been collected, these linguistic values are transformed into fuzzy values. In this process, a defined membership function is used that determines which fuzzy number the linguistic value will be transformed into. In this research, the membership function is defined as follows: very bad – (1, 1, 2), bad – (1, 2, 4), medium bad – (2, 4, 6), medium – (3, 5, 7), medium good – (5, 7, 9), good – (7, 9, 9), very good – (9, 10, 10). After the linguistic values have been transformed into fuzzy numbers, a collective initial fuzzy decision matrix is formed (table 2). This matrix is formed by giving each expert the same importance and finding the average value of fuzzy numbers for all criteria and observed tractors.

Table 2. Summary initial decision matrix.

	C1	C2	C3	C4	...	C11
T1	(8.0, 9.4, 9.9)	(7.3, 8.9, 9.8)	(7.5, 9.3, 10.0)	(7.0, 8.6, 9.6)	...	(7.3, 9.0, 9.9)
T2	(7.3, 8.8, 9.6)	(5.3, 7.3, 8.8)	(6.5, 8.3, 9.4)	(6.3, 8.1, 9.4)	...	(5.8, 7.6, 9.3)
T3	(6.0, 8.0, 9.4)	(5.3, 7.3, 8.8)	(6.3, 8.0, 9.3)	(5.8, 7.8, 9.3)	...	(5.8, 7.8, 9.3)
T4	(7.8, 9.1, 9.8)	(6.8, 8.5, 9.6)	(6.8, 8.5, 9.6)	(6.0, 8.0, 9.5)	...	(5.3, 7.3, 9.1)
T5	(6.3, 8.1, 9.5)	(5.5, 7.4, 9.0)	(6.8, 8.6, 9.8)	(6.0, 7.8, 9.1)	...	(5.4, 7.4, 9.0)
T6	(6.0, 7.8, 9.1)	(6.5, 8.4, 9.5)	(5.1, 7.0, 8.6)	(7.0, 8.8, 9.6)	...	(6.0, 8.0, 9.5)
T7	(6.3, 8.0, 9.3)	(6.0, 7.8, 9.1)	(6.0, 7.9, 9.3)	(6.3, 8.1, 9.5)	...	(6.3, 8.1, 9.5)
T8	(6.0, 8.0, 9.5)	(6.5, 8.3, 9.4)	(5.5, 7.4, 9.0)	(6.3, 8.1, 9.4)	...	(4.9, 6.9, 8.5)
T9	(6.8, 8.4, 9.5)	(6.0, 7.9, 9.3)	(5.3, 7.3, 9.0)	(6.4, 8.3, 9.4)	...	(5.4, 7.4, 9.0)
T10	(5.8, 7.8, 9.4)	(7.3, 9.0, 9.9)	(6.3, 8.1, 9.5)	(6.3, 8.1, 9.4)	...	(5.8, 7.8, 9.1)
T11	(6.3, 8.1, 9.5)	(6.5, 8.4, 9.5)	(5.3, 7.1, 8.8)	(7.0, 8.9, 9.9)	...	(5.0, 7.0, 8.6)
T12	(6.3, 8.0, 9.3)	(6.0, 7.8, 9.0)	(6.3, 8.3, 9.6)	(6.8, 8.4, 9.4)	...	(5.5, 7.4, 9.0)
T13	(6.5, 8.4, 9.6)	(6.5, 8.3, 9.4)	(6.0, 7.9, 9.3)	(6.3, 8.1, 9.5)	...	(5.3, 7.3, 9.0)
T14	(7.3, 8.8, 9.5)	(5.8, 7.4, 8.6)	(5.5, 7.5, 9.0)	(5.3, 7.3, 9.0)	...	(6.5, 8.4, 9.6)
T15	(8.8, 9.9, 10.0)	(8.0, 9.3, 9.6)	(7.3, 8.8, 9.5)	(7.3, 8.8, 9.6)	...	(7.6, 9.0, 9.5)
T16	(6.3, 8.1, 9.5)	(6.5, 8.3, 9.5)	(5.8, 7.6, 9.1)	(6.0, 8.0, 9.4)	...	(5.5, 7.4, 9.0)
T17	(6.3, 8.0, 9.3)	(5.8, 7.6, 9.1)	(5.5, 7.5, 9.0)	(4.8, 6.8, 8.6)	...	(5.5, 7.5, 9.1)

The next step is the normalization of the collective fuzzy decision matrix. Both selected methods use the same normalization. In the normalization process, the smallest and largest fuzzy number is taken for a certain criterion. The smallest value of the fuzzy number for that criterion is then subtracted from the individual value of the tractor, and this is put in relation to the largest value of the fuzzy number, which is reduced by the smallest value of the fuzzy number. Applying this normalization process, the largest value of the fuzzy number is normalized to the number one (1), while the smallest value of the fuzzy number for a certain criterion is normalized to the number zero (0). Using the example of tractor T1 and criterion C1, the normalization calculation process is performed as follows:

$$n_{11} = \left(\frac{8.0 - 5.8}{10.0 - 5.8} = 0.53, \frac{9.4 - 5.8}{10.0 - 5.8} = 0.85, \frac{9.9 - 5.8}{10.0 - 5.8} = 0.97 \right)$$

Since, after normalization, the fuzzy MABAC method is used to make a weighting, which requires the weight of the criteria, it is necessary to first calculate the weights of the criteria and only then rank the observed tractors. For this reason, the steps of the fuzzy LOPCOW method are performed first. First, the percentage (PV) is calculated and then the weight of the criteria. When calculating the percentage (PV), all normalized values must be scaled and then added up and divided by the number of criteria used in this research. This amount is then square-rooted and then divided by the amount of the standard deviation, which is calculated individually for all fuzzy criteria numbers. The obtained amount is multiplied by the number 100 and the natural logarithm of this amount is calculated and the absolute value is calculated. The findings obtained using the fuzzy LOPCOW method (table 3) demonstrated that there is no significant difference in the weight values of all criteria. In this way, it can be said that these criteria equally participate in the ranking of tractors.

Table 3. Criterion weights obtained by the fuzzy LOPCOW method.

	C1	C2	C3	C4	...	C11
PV	(5.26, 6.37, 7.67)	(5.42, 6.41, 7.27)	(5.38, 6.40, 7.30)	(5.80, 6.71, 7.67)	...	(5.32, 6.41, 7.39)
w	(0.06, 0.09, 0.13)	(0.07, 0.09, 0.12)	(0.07, 0.09, 0.12)	(0.07, 0.10, 0.13)	...	(0.07, 0.09, 0.12)

Then, when applying the hybrid fuzzy LOPCOW-MABAC method, the weighting of the normalized values is carried out in such a way that the normalized values are multiplied by the obtained weights and then this value is increased by the weight value of the criterion. Then a threshold value is calculated, which represents the value of the geometric mean of the weighted values according to a certain criterion. After that, the deviations of the weighted values from the limit value are calculated and the collective deviation is calculated for certain

tractors. At the end, these values are defuzzified and the tractors are ranked (table 4). By applying these steps of the fuzzy MABAC method, findings were obtained that show that the best ranked tractor is T15, followed by tractor T1. According to experts, the worst findings were obtained by tractor T17. The best-ranked tractor is an electric tractor that is ranked best due to its specifics and environmental friendliness. In this way, it was shown that electric tractors can fight on an equal footing with classic tractors powered by a diesel engine.

Table 4. Ranking of tractors using the fuzzy MABAC method.

	$\tilde{S}_i$	S_i	Rank
T1	(-1.54, 0.19, 1.84)	0.180	2
T2	(-1.72, -0.02, 1.69)	-0.019	9
T3	(-1.75, -0.05, 1.67)	-0.043	14
T4	(-1.64, 0.08, 1.77)	0.074	3
T5	(-1.73, -0.04, 1.67)	-0.037	12
T6	(-1.73, -0.04, 1.66)	-0.040	13
T7	(-1.70, -0.01, 1.70)	-0.005	7
T8	(-1.76, -0.07, 1.65)	-0.064	16
T9	(-1.73, -0.04, 1.68)	-0.035	11
T10	(-1.71, -0.01, 1.70)	-0.005	8
T11	(-1.70, 0.00, 1.70)	0.001	5
T12	(-1.69, 0.01, 1.71)	0.011	4
T13	(-1.71, 0.00, 1.71)	-0.003	6
T14	(-1.76, -0.07, 1.66)	-0.061	15
T15	(-1.42, 0.28, 1.83)	0.256	1
T16	(-1.73, -0.04, 1.69)	-0.032	10
T17	(-1.79, -0.11, 1.63)	-0.097	17

In order to confirm these findings, a comparison was made with the findings of other fuzzy methods [38]. Eight other methods were used for this purpose, namely: fuzzy RAWEC (Ranking of Alternatives with Weights of Criterion), fuzzy MARCOS (Measurement of Alternatives and Ranking according to Compromise Solution), fuzzy WASPAS (Weighted Aggregated Sum Product Assessment), fuzzy SAW, fuzzy ARAS (Additive Ratio Assessment), fuzzy TOPSIS, fuzzy VIKOR (ser. VlseKriterijuska Optimizacija I Compromise Solution) and fuzzy CRADIS. All of these methods have their own specific steps, so their rankings may differ [39-41]. The findings of this analysis show (Figure 2) that the ranking order of the first four tractors is the same for all methods, and these tractors represent the best choices for farmers in the Myzeqe area. After these four best ranked tractors, the ranking of the ancestor changes with the application of the steps of these methods. Thus, the fuzzy VIKOR method has the biggest deviations from the other methods in the ranking order, while the ranking order of the T13 tractor differs the most when these methods are used.

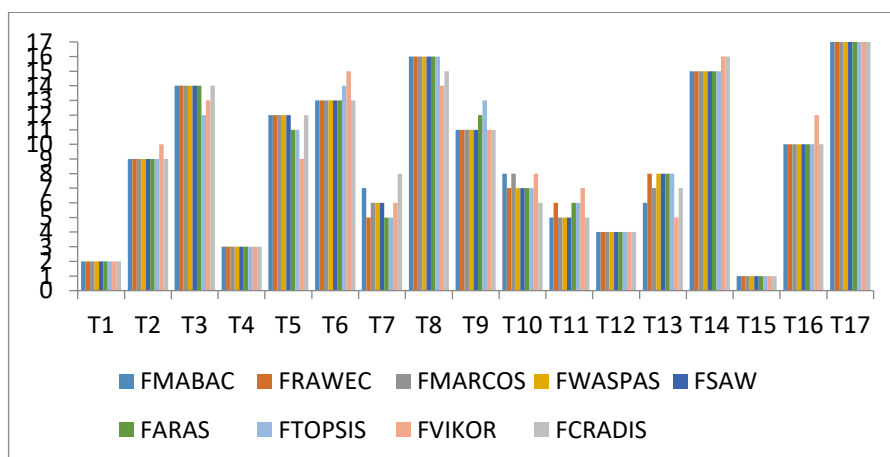


Figure 2. Comparison results with other fuzzy methods.

At the end of the findings of this research, a sensitivity analysis will be performed [42-47]. In this analysis, 12 scenarios are applied, and in the first scenario, all criteria are given the same importance, while in the other criteria, one criterion is given two and a half times priority over the other criteria, and in this way the other 11 scenarios are formed. The findings of this analysis show that the ranking order of the first three first-placed tractors did not change in all scenarios (figure 3), while the ranking order of the other tractors changed depending on which criterion was given greater importance. For example, the T12 tractor was placed fourth by applying the weights obtained by the LOPCOW method. By applying other scenarios, in eight scenarios it was placed fourth, while in scenarios S3 and S9 it was in sixth place. The reason for this should be found in the fact that with criteria C2 and C8, this tractor had slightly worse grades, so with the increase in their weights, its ranking order was worse. These findings show which criteria individual tractors need to improve in order to be as good as possible. In this way, the findings of the sensitivity analysis can show which the bad are and which are the good sides of these tractors and what they need to improve in order to be better than other tractors. The changes in the ranking order in the sensitivity analysis showed that some criteria particularly affect these changes. It is necessary to see how each criterion affects the ranking of a particular tractor, if there is an improvement in the ranking, it means that that tractor should improve that criterion and vice versa. In this way, sensitivity analysis can be used to improve the characteristics of individual tractors so that that tractor is better for application in the Myzeqe area of Albania.

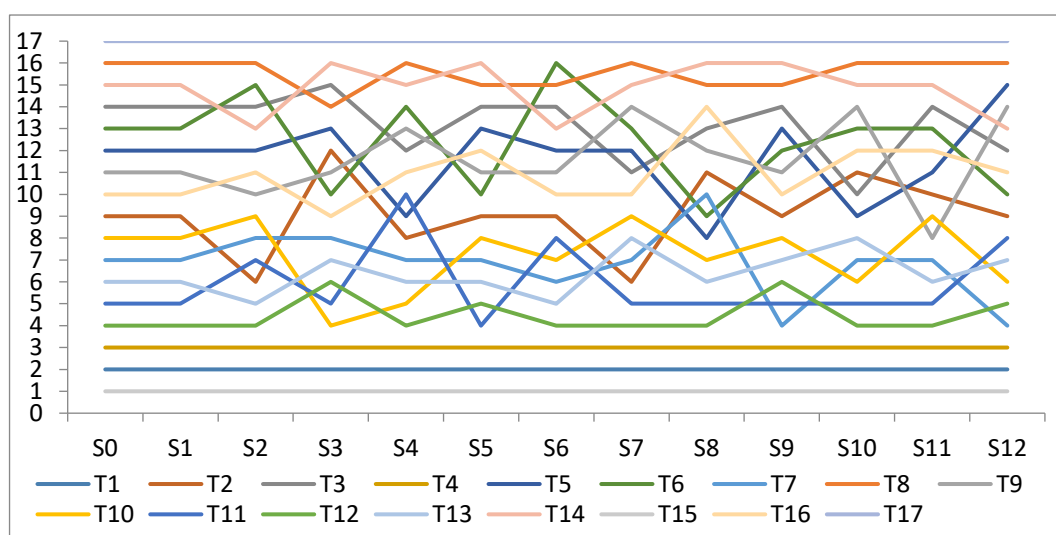


Figure 3. Results of the sensitivity analysis.

5 Discussion and conclusion

The application of agriculture is unthinkable without the use of agricultural machinery, of which the tractor is the most crucial. Buying a tractor represents an investment for the farmer, so they should choose the tractor that will best meet their needs. This research dealt with the evaluation of tractors in the Myzeqe area of Albania for the needs of small and medium-sized agricultural producers, since there are the most of them in this area. For this purpose, a decision-making model was created that included 11 criteria and 17 tractors. However, apart from the fact that different criteria and tractors are included, it is always possible to take different criteria and include some other tractors. This represents the biggest weakness of this model because it is never possible to include all criteria and tractors. The selected criteria were mostly focused on the technical characteristics of the tractor and to a lesser extent on economic and ecological criteria. In order to solve this decision-making model, a hybrid fuzzy methodology based on the LOPCOW and MABAC methods was formed. We took advantage of the fact that both of these methods apply the same normalization, so the steps of one method were complemented by the steps of the other method. The approach used in this way provides opportunities for developing similar approaches in future research. In order to apply this hybrid methodology, expert decision-making involving 8 experts was used. These experts used linguistic values to evaluate the selected tractors in this research according to defined criteria. Based on this, a summary decision-making matrix was formed and selected methods were used. The findings of applying the fuzzy LOPCOW method demonstrated that the

findings of criteria weights are similar for all criteria. No significant preference is given to any of the criteria. The reason for this should be found in the evaluations given by the experts. There was not too much difference between them, so the dispersion in the grades was similar, and that is why the criteria were given similar weights. In this way, certain criteria were not favored, so they did not influence the final decision. In order to determine which tractors show the best characteristics for farmers, the fuzzy MABAC method was used. Applying this method, it was determined that the T15 tractor shows the best findings. This tractor is also an electric tractor that works using batteries and an electric motor. This tractor does not pollute the environment with its operation, but unlike other tractors, it requires charging that lasts for hours.

This is why this tractor can be used for a certain amount of time as long as there is energy in the battery. After that, it is necessary to connect the tractor to the charger. In addition, this tractor was chosen as the best probably because the experts took into account that the development of agriculture should be based on sustainability. This was confirmed by performing a comparison with other fuzzy methods and by performing a sensitivity analysis. In both of these analyses, this particular tractor achieved the best findings. These analyses then demonstrated that the ranking order of these tractors can be changed, because there is little difference in their characteristics. Therefore, the purpose of this research was to recommend which tractors would give the best findings in agricultural production in the Myzeqe area. However, this does not necessarily mean that in some other district or some other country, this order of observed tractors would be the same. When applying the methodology based on the fuzzy LOPCOW and MABAC methods, it was used that both methods have the same normalization and that they use the same decision matrix. In the case of future research, it is possible to combine other methods and ensure that the same initial decision matrix and the same normalization are used. Thus, it is possible to combine the CRITIC (criteria importance through intercriteria correlation) method with the MABAC or CoCoSo (combined compromise solution) method, the Entropy method with all methods that use linear normalization. So, it is necessary to reduce the number of calculations in the decision-making model in order to facilitate the work of decision-makers. In future research, it is necessary to solve the limits of this research, which refer to the criteria and alternatives used in this research. It is necessary to first determine the importance of a number of criteria and choose which are the most crucial among them and use them in practice. After that, it is necessary to base the choice of tractor on the new types and brands that appear on the market. New types and brands come out every day to replace previous types and brands.

This is why selecting an optimal tractor is a constant choice faced by agricultural producers. Choosing the wrong tractor will reduce the effects of production. Based on that, this research gave guidelines on how to implement this decision-making in agriculture, which is based mostly on the tractor's characteristics, and then other criteria related to price or effects on the environment are also included. In addition, this research also provided guidelines on how to improve agricultural production using a hybrid methodology based on fuzzy methods. This research has established guidelines for improving agricultural production in Albania. Future research should be directed to other regions in Albania as well as to other segments of agricultural production. Research can be conducted in other agricultural regions in Albania that have other agricultural crops. For example, the model can be applied in the region of Korça because this region is known for the production of apples, potatoes and beans, the region of Saranda is known for the production of tangerines, the region of Shkodra where the medicinal plant known as *Salvia officinalis* L. is grown, where Albania is one of the largest producers that exports to the USA. Future research could be directed into these and related areas.

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