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Selection Optimal Livestock Location under Multi-Criteria Decision Making Fuzzy Framework

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Abstract

As a primary provider of food resources for humans, the livestock sector is now crucial to achieving the internationally recognized sustainable development goals. General policies are required to direct the cattle business in a sustainable way in terms of the economy, society, and environment. Sustainable development objectives should be included in these strategies, considering unique geographical circumstances and current hazards. The first stage in attaining sustainable growth in the livestock sector is to choose appropriate locations while considering related dangers. This study suggested multi-criteria decision-making (MCDM) methodology for dealing with various conflicting criteria by selecting optimal livestock locations. The MCDM methodology integrated with the trapezoidal fuzzy set to deal with uncertain and vague information. The WASPAS method is used to rank the alternatives. There are 11 criteria, and 10 locations are used in this study. A sensitivity analysis was conducted to show that the results were stable.

Keywords: Livestock; Selection Process; Fuzzy Set; Multi-Criteria Decision Making; Food Security.

1 | Introduction

The world's hunger rate is still startlingly high. Fifty-three nations are home to almost 193 million food-insecure individuals urgently needing aid. The latest figure surpasses the previous record established in 2020 by around 40 million hungry individuals. The forecast for severe food insecurity in 2022 will worsen even more compared to 2021. In particular, the Ukraine conflict is anticipated to exacerbate the already severe projections for food insecurity in 2022. The Millennium Development Goals (MDGs) have drawn attention worldwide; their primary goal is to end extreme poverty and hunger while managing the planet's natural resources in an environmentally responsible manner. The second objective of the Sustainable Development Goals (SDGs) is to find sustainable ways to achieve food safety and eradicate all kinds of hunger by 2030. This objective primarily makes sure that every person has a means of getting enough nutritious food for a healthy existence [1, 2].

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The livestock sector plays a crucial role in agricultural growth, food safety, and poverty alleviation, serving as the backbone of the world food system. Numerous studies have shown how the raising of cattle significantly impacts people's diets and health. The cattle industry's contribution to the food supplies, economies, and cultural fabric of rural and urban communities is undeniable. For instance, the impoverished in East Africa derive 11% of their calories and 26% of their protein from the cattle business. This underscores the potential of the cattle industry to contribute to long-term food safety and poverty reduction [3, 4].

Both theoretical criteria and actual data support the importance of investing in the livestock industry and its effect on the sector's performance. Investing in cattle will increase output and jobs in other industries. Considering the high unemployment rates in many areas, investing in the cattle industry and associated productive endeavors may result in profoundly revolutionary improvements. The growth of the cattle business significantly impacts employment creation, eradicating poverty and deprivation, transformation, and the auxiliary sectors [5, 6].

The cattle industry must simultaneously solve its social, ecological, and financial issues to develop sustainably. Increasing the economic viability of livestock production and maintaining a balance between meeting the increasing need for animal goods and reducing the negative impacts and negatives of the livestock sector are necessary for sustainable livestock production. The government's objectives for economic development are significantly advanced by the rapid pace of livestock growth in tandem with population increase. In addition to maximizing spatial productivity, lowering expenses, and guaranteeing the proper distribution of services, which promotes citizen tranquility, good choice of location also fosters better relationships between members of different social groups. Appropriately identifying industrial centers and their service dispersion is essential for regional growth planning [7, 8].

The incorrect site not only raises manufacturing costs but also causes environmental problems that impede the company's expansion. Therefore, picking a suitable site for the cattle industry's growth is suggested as a workable strategy to lessen the effects on the environment, society, and economy [9, 10].

The paper's objective is to present an extensive method for choosing the location of livestock, considering the uncertainty and evaluation dynamics associated with many significant requirements for ongoing enhancement. The Weighted Aggregated Sum Product Assessment (WASPAS) technique of multi-criteria decision-making (MCDM) under fuzzy set theory, which builds upon Zadeh's fuzzy sets approach, is proposed as a robust tool for this purpose. This method, with its ability to handle uncertainty and vague information, instills confidence in the decision-making process [11, 12].

The most well-known type of decision-making is MCDM. When evaluating options, discrete numbers or intervals are inappropriate when the decision-maker's preferences and judgments are unclear. Next, it is suggested that the so-called fuzzy MCDM (FMCDM) methods be created by fusing MCDM techniques with fuzzy set theory. In FMCDM approaches, language phrases detected primarily with fuzzy sets derive judgments and preferences [13-15].

The contributions of this study are:

i. Select the best location for livestock for food safety.

ii. The selection of location under fuzzy sets to deal with uncertainty and vague information.

iii. The WASPAS method was used to rank the locations.

iv. A sensitivity analysis was conducted to show that the rank was stable.

The rest of this paper is organized as follows: Section 2 presents the fuzzy framework and steps of the WASPAS method for ranking livestock locations under different criteria. Section 3 presents the results of selecting the best location using the WASPAS method. Section 4 presents the conclusions of this study.

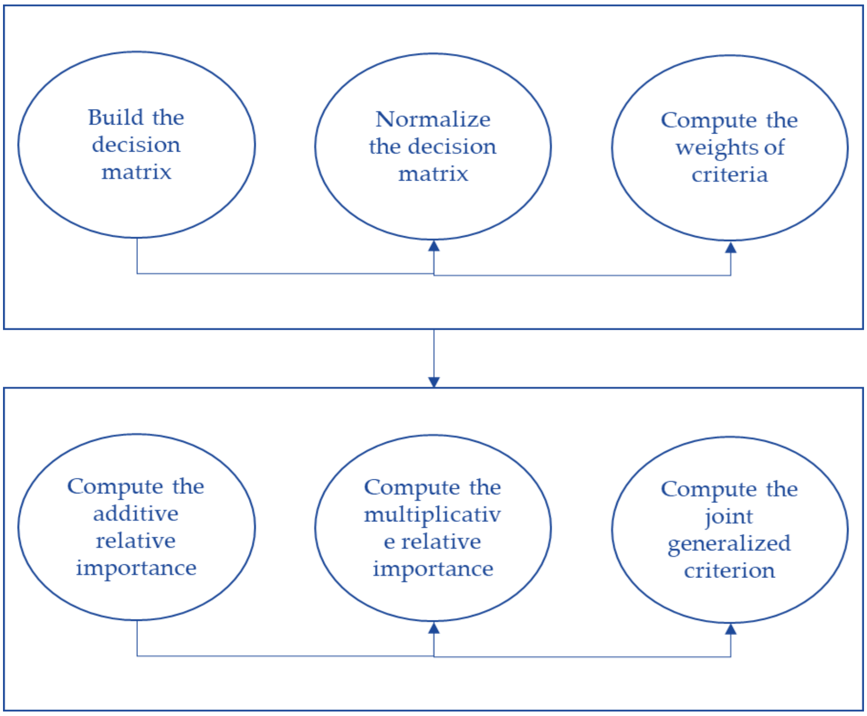

Figure 1. The steps of the fuzzy WASPAS method.

2 | Fuzzy Framework

This section integrates the trapezoidal fuzzy sets with the MCDM methodology to rank the alternatives. The WASPAS method used to rank the livestock location in Egypt. The WASPAS method is a MCDM method. WASPAS method combine weighted sum model (WSM) and weighted product model (WPM) [16-18]. Figure 1 shows the steps of the fuzzy WASPAS method.

Step 1. Build the decision matrix.

$$y = \begin{bmatrix} y_{11} & \cdots & y_{1n} \\ \vdots & \ddots & \vdots \\ y_{m1} & \cdots & y_{mn} \end{bmatrix}; \quad i = 1,2,\dots,m; j = 1,2,\dots,n. \tag{1}$$

Step 2. Normalize the decision matrix. Normalize the decision matrix for positive and negative criteria.

$$y_{ij}^{*} = \frac{y_{ij}}{\max\limits_{i} y_{ij}}; \ i = 1,2,\dots,m; j = 1,2,\dots,n. \tag{2}$$

$$y_{ij}^{*} = \frac{\min\limits_{i} y_{ij}}{y_{ij}}; \ i = 1,2,\dots,m; j = 1,2,\dots,n. \tag{3}$$

Step 3. Compute the weights of criteria.

Step 4. Compute the additive relative importance. The weighted normalized decision matrix as:

$$u_i^{(1)} = \sum_{j=1}^{n} y_{ij}^{*} w_j; i = 1,2,\dots,m; j = 1,2,\dots,n. \tag{4}$$

Step 5. Compute the multiplicative relative importance.

$$u_i^{(2)} = \prod_{j=1}^{n} \left(y_{ij}^{*}\right)^{w_j}; \ i = 1,2,\dots,m; j = 1,2,\dots,n. \tag{5}$$

Step 6. Compute the joint generalized criterion.

$$u_i = \beta u_i^{(1)} + (1-\beta) u_i^{(2)}; \ \beta \in [0,1] \tag{6}$$

Step 7. Rank the alternatives.

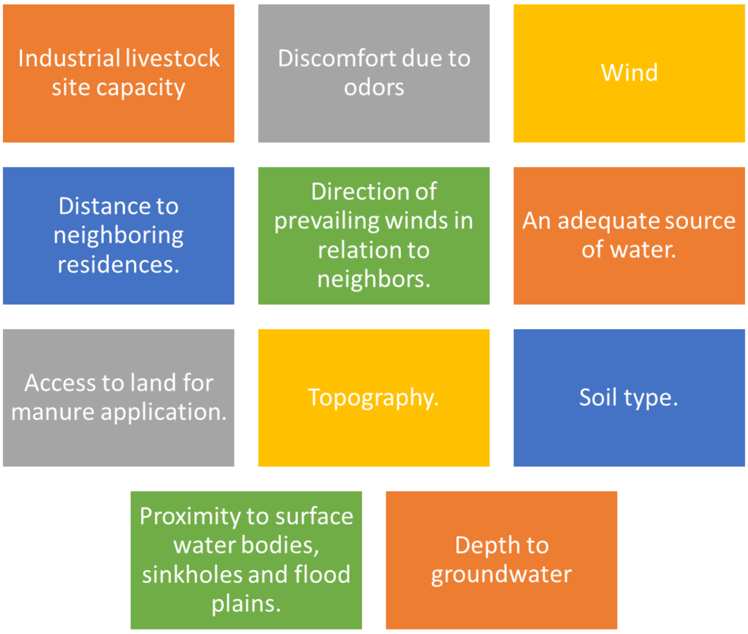

Figure 2. Livestock site selection criteria.

3 | Results

This section introduces the results of the fuzzy WASPAS method to rank the livestock location in Egypt. Three experts are invited to select optimal criteria of this study as shown in Figure 2. Then we used the linguistic variables of fuzzy sets [19] to evaluate the criteria. We replaced these variables by trapezoidal fuzzy sets as shown in Tables 1-3.

Step 1. Build the decision matrix. The decision matrices are built by using trapezoidal fuzzy numbers [19] by using Eq. (1) as shown in Table 1.

Step 2. Normalize the decision matrix for positive and negative criteria by using Eqs. (2) and (3) as shown in Table 4. All criteria are positive.

Step 3. Compute the weights of criteria as shown in Figure 3.

Step 4. Compute the additive relative importance by using Eq. (4).

Step 5. Compute the multiplicative relative importance by using Eq. (5).

Step 6. Compute the joint generalized criterion by using Eq. (6) as shown in Figure 4. We put value of β with 0.5.

Step 7. Rank the alternatives. The alternative 1 is the best and alternative 10 is the worst.

Table 1. The first expert opinions in the decision matric.

	LSC_1	LSC_2	LSC_3	LSC_4	LSC_5	LSC_6	LSC_7	LSC_8	LSC_9	LSC_{10}	LSC_{11}
LSA_1	(1,1,2,3)	(2,3,4,5)	(4,5,6,7)	(6,7,8,9)	(8,9,10,10)	(1,1,2,3)	(2,3,4,5)	(2,3,4,5)	(4,5,6,7)	(6,7,8,9)	(8,9,10,10)
LSA_2	(2,3,4,5)	(1,1,2,3)	(2,3,4,5)	(1,1,2,3)	(1,1,2,3)	(8,9,10,10)	(1,1,2,3)	(1,1,2,3)	(8,9,10,10)	(1,1,2,3)	(8,9,10,10)
LSA_3	(2,3,4,5)	(2,3,4,5)	(1,1,2,3)	(2,3,4,5)	(1,1,2,3)	(6,7,8,9)	(1,1,2,3)	(2,3,4,5)	(6,7,8,9)	(2,3,4,5)	(1,1,2,3)
LSA_4	(6,7,8,9)	(2,3,4,5)	(2,3,4,5)	(2,3,4,5)	(2,3,4,5)	(1,1,2,3)	(2,3,4,5)	(1,1,2,3)	(4,5,6,7)	(2,3,4,5)	(2,3,4,5)
LSA_5	(6,7,8,9)	(1,1,2,3)	(2,3,4,5)	(6,7,8,9)	(2,3,4,5)	(2,3,4,5)	(2,3,4,5)	(2,3,4,5)	(1,1,2,3)	(6,7,8,9)	(2,3,4,5)
LSA_6	(8,9,10,10)	(2,3,4,5)	(6,7,8,9)	(1,1,2,3)	(6,7,8,9)	(2,3,4,5)	(6,7,8,9)	(2,3,4,5)	(2,3,4,5)	(4,5,6,7)	(6,7,8,9)
LSA_7	(8,9,10,10)	(2,3,4,5)	(8,9,10,10)	(2,3,4,5)	(2,3,4,5)	(6,7,8,9)	(2,3,4,5)	(6,7,8,9)	(2,3,4,5)	(6,7,8,9)	(6,7,8,9)
LSA_8	(2,3,4,5)	(6,7,8,9)	(4,5,6,7)	(1,1,2,3)	(4,5,6,7)	(8,9,10,10)	(6,7,8,9)	(4,5,6,7)	(6,7,8,9)	(4,5,6,7)	(8,9,10,10)
LSA_9	(6,7,8,9)	(8,9,10,10)	(4,5,6,7)	(6,7,8,9)	(6,7,8,9)	(2,3,4,5)	(8,9,10,10)	(1,1,2,3)	(2,3,4,5)	(4,5,6,7)	(8,9,10,10)
LSA_{10}	(4,5,6,7)	(6,7,8,9)	(4,5,6,7)	(4,5,6,7)	(2,3,4,5)	(1,1,2,3)	(8,9,10,10)	(6,7,8,9)	(6,7,8,9)	(2,3,4,5)	(1,1,2,3)

Table 2. The second expert opinions in the decision matric.

	LSC_1	LSC_2	LSC_3	LSC_4	LSC_5	LSC_6	LSC_7	LSC_8	LSC_9	LSC_{10}	LSC_{11}
LSA_1	(2,3,4,5)	(2,3,4,5)	(8,9,10,10)	(8,9,10,10)	(8,9,10,10)	(1,1,2,3)	(2,3,4,5)	(8,9,10,10)	(4,5,6,7)	(6,7,8,9)	(8,9,10,10)
LSA_2	(2,3,4,5)	(1,1,2,3)	(8,9,10,10)	(8,9,10,10)	(1,1,2,3)	(8,9,10,10)	(1,1,2,3)	(8,9,10,10)	(8,9,10,10)	(8,9,10,10)	(8,9,10,10)
LSA_3	(8,9,10,10)	(2,3,4,5)	(1,1,2,3)	(1,1,2,3)	(8,9,10,10)	(8,9,10,10)	(1,1,2,3)	(1,1,2,3)	(6,7,8,9)	(8,9,10,10)	(1,1,2,3)
LSA_4	(8,9,10,10)	(2,3,4,5)	(2,3,4,5)	(2,3,4,5)	(8,9,10,10)	(1,1,2,3)	(8,9,10,10)	(2,3,4,5)	(8,9,10,10)	(1,1,2,3)	(2,3,4,5)
LSA_5	(1,1,2,3)	(8,9,10,10)	(2,3,4,5)	(8,9,10,10)	(1,1,2,3)	(2,3,4,5)	(8,9,10,10)	(2,3,4,5)	(8,9,10,10)	(2,3,4,5)	(8,9,10,10)
LSA_6	(2,3,4,5)	(8,9,10,10)	(6,7,8,9)	(8,9,10,10)	(2,3,4,5)	(2,3,4,5)	(1,1,2,3)	(2,3,4,5)	(1,1,2,3)	(4,5,6,7)	(8,9,10,10)
LSA_7	(2,3,4,5)	(1,1,2,3)	(8,9,10,10)	(1,1,2,3)	(2,3,4,5)	(6,7,8,9)	(2,3,4,5)	(6,7,8,9)	(2,3,4,5)	(6,7,8,9)	(1,1,2,3)
LSA_8	(2,3,4,5)	(2,3,4,5)	(4,5,6,7)	(2,3,4,5)	(4,5,6,7)	(8,9,10,10)	(6,7,8,9)	(4,5,6,7)	(6,7,8,9)	(4,5,6,7)	(2,3,4,5)
LSA_9	(6,7,8,9)	(8,9,10,10)	(4,5,6,7)	(6,7,8,9)	(6,7,8,9)	(2,3,4,5)	(8,9,10,10)	(1,1,2,3)	(2,3,4,5)	(4,5,6,7)	(8,9,10,10)
LSA_{10}	(4,5,6,7)	(2,3,4,5)	(4,5,6,7)	(4,5,6,7)	(2,3,4,5)	(1,1,2,3)	(8,9,10,10)	(6,7,8,9)	(6,7,8,9)	(2,3,4,5)	(1,1,2,3)

Table 3. The third expert opinions in the decision matric.

	LSC_1	LSC_2	LSC_3	LSC_4	LSC_5	LSC_6	LSC_7	LSC_8	LSC_9	LSC_{10}	LSC_{11}
LSA_1	(6,7,8,9)	(2,3,4,5)	(6,7,8,9)	(6,7,8,9)	(8,9,10,10)	(1,1,2,3)	(6,7,8,9)	(2,3,4,5)	(4,5,6,7)	(6,7,8,9)	(8,9,10,10)
LSA_2	(8,9,10,10)	(1,1,2,3)	(8,9,10,10)	(1,1,2,3)	(1,1,2,3)	(8,9,10,10)	(8,9,10,10)	(6,7,8,9)	(8,9,10,10)	(6,7,8,9)	(8,9,10,10)
LSA_3	(4,5,6,7)	(6,7,8,9)	(4,5,6,7)	(6,7,8,9)	(6,7,8,9)	(6,7,8,9)	(4,5,6,7)	(8,9,10,10)	(6,7,8,9)	(8,9,10,10)	(1,1,2,3)
LSA_4	(4,5,6,7)	(8,9,10,10)	(4,5,6,7)	(8,9,10,10)	(8,9,10,10)	(1,1,2,3)	(4,5,6,7)	(4,5,6,7)	(4,5,6,7)	(4,5,6,7)	(6,7,8,9)
LSA_5	(6,7,8,9)	(4,5,6,7)	(2,3,4,5)	(4,5,6,7)	(4,5,6,7)	(2,3,4,5)	(2,3,4,5)	(4,5,6,7)	(1,1,2,3)	(4,5,6,7)	(8,9,10,10)
LSA_6	(6,7,8,9)	(4,5,6,7)	(6,7,8,9)	(4,5,6,7)	(4,5,6,7)	(6,7,8,9)	(6,7,8,9)	(2,3,4,5)	(6,7,8,9)	(4,5,6,7)	(4,5,6,7)
LSA_7	(8,9,10,10)	(2,3,4,5)	(8,9,10,10)	(2,3,4,5)	(2,3,4,5)	(8,9,10,10)	(8,9,10,10)	(6,7,8,9)	(8,9,10,10)	(6,7,8,9)	(4,5,6,7)
LSA_8	(4,5,6,7)	(6,7,8,9)	(4,5,6,7)	(1,1,2,3)	(4,5,6,7)	(4,5,6,7)	(4,5,6,7)	(4,5,6,7)	(4,5,6,7)	(4,5,6,7)	(8,9,10,10)
LSA_9	(4,5,6,7)	(8,9,10,10)	(4,5,6,7)	(6,7,8,9)	(6,7,8,9)	(4,5,6,7)	(4,5,6,7)	(1,1,2,3)	(4,5,6,7)	(4,5,6,7)	(8,9,10,10)
LSA_{10}	(4,5,6,7)	(6,7,8,9)	(4,5,6,7)	(4,5,6,7)	(2,3,4,5)	(1,1,2,3)	(8,9,10,10)	(6,7,8,9)	(6,7,8,9)	(2,3,4,5)	(1,1,2,3)

Table 4. The normalized decision matric.

	LSC_1	LSC_2	LSC_3	LSC_4	LSC_5	LSC_6	LSC_7	LSC_8	LSC_9	LSC_{10}	LSC_{11}
LSA_1	0.575	0.379518	0.803213	1	1	0.192771	0.524096	0.720988	0.596386	1	1
LSA_2	0.73	0.192771	0.793173	0.527523	0.192771	1	0.461847	0.822222	1	0.822222	1
LSA_3	0.82	0.524096	0.327309	0.527523	0.668675	0.875502	0.327309	0.644444	0.813253	0.975309	0.192771
LSA_4	1	0.586345	0.451807	0.669725	0.793173	0.192771	0.658635	0.479012	0.730924	0.479012	0.524096
LSA_5	0.755	0.596386	0.379518	0.917431	0.389558	0.379518	0.586345	0.555556	0.461847	0.733333	0.793173
LSA_6	0.91	0.658635	0.813253	0.681193	0.596386	0.524096	0.606426	0.466667	0.461847	0.733333	0.803213
LSA_7	0.9875	0.317269	1	0.362385	0.379518	0.875502	0.586345	1	0.586345	1	0.534137
LSA_8	0.5625	0.668675	0.596386	0.291284	0.596386	0.865462	0.740964	0.733333	0.740964	0.733333	0.793173
LSA_9	0.9225	1	0.596386	0.928899	0.813253	0.451807	0.865462	0.237037	0.451807	0.733333	1
LSA_{10}	0.7425	0.668675	0.596386	0.681193	0.379518	0.192771	1	1	0.813253	0.466667	0.192771

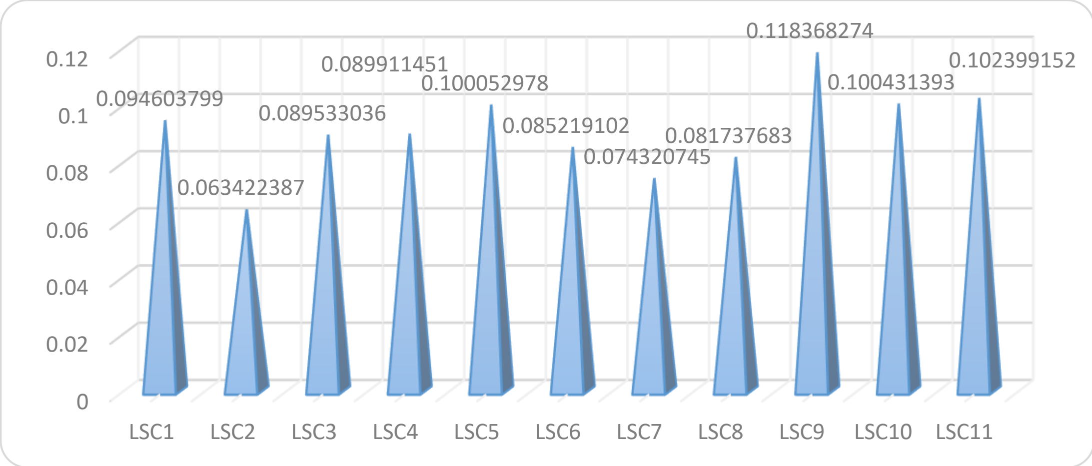

Figure 3. The weights of criteria.

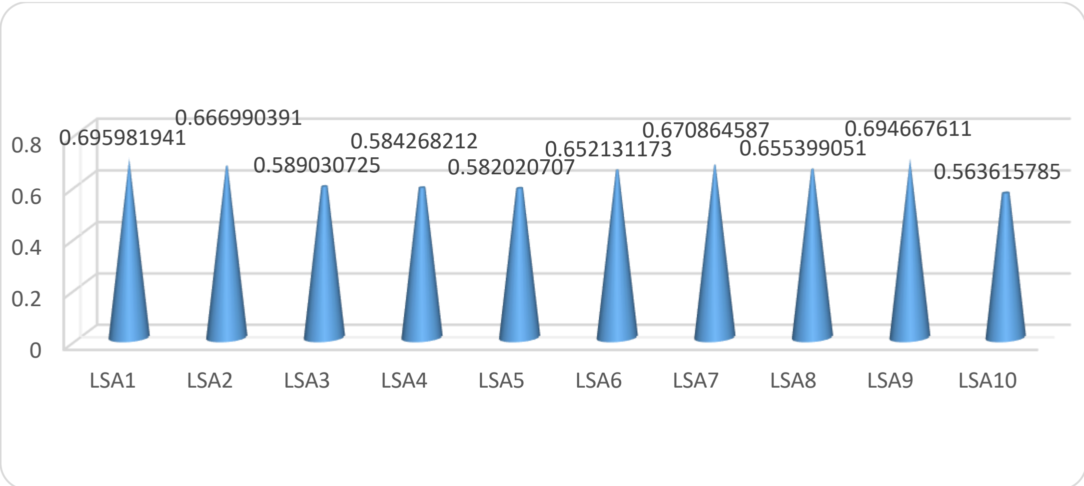

Figure 4. The values of alternatives under joint generalized criterion.

We change the value of β between 0 and 1 then we applied the WASPAS method to show the rank of alternatives under different values. We compute the joint generalized criterion values as shown in Figure 5. Then we rank the alternatives as shown in Figure 6. We show alternative 9 is the best in β *between* 0 *to* 0.3 and the alternative 1 is best in other values.

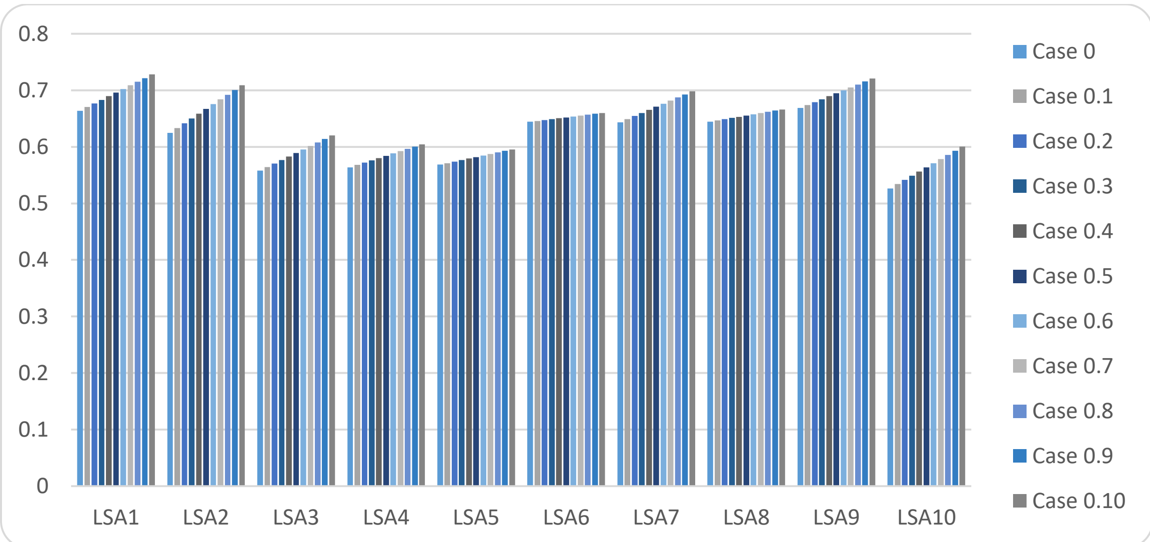

Figure 5. The values of alternatives under joint generalized criterion under different values of β.

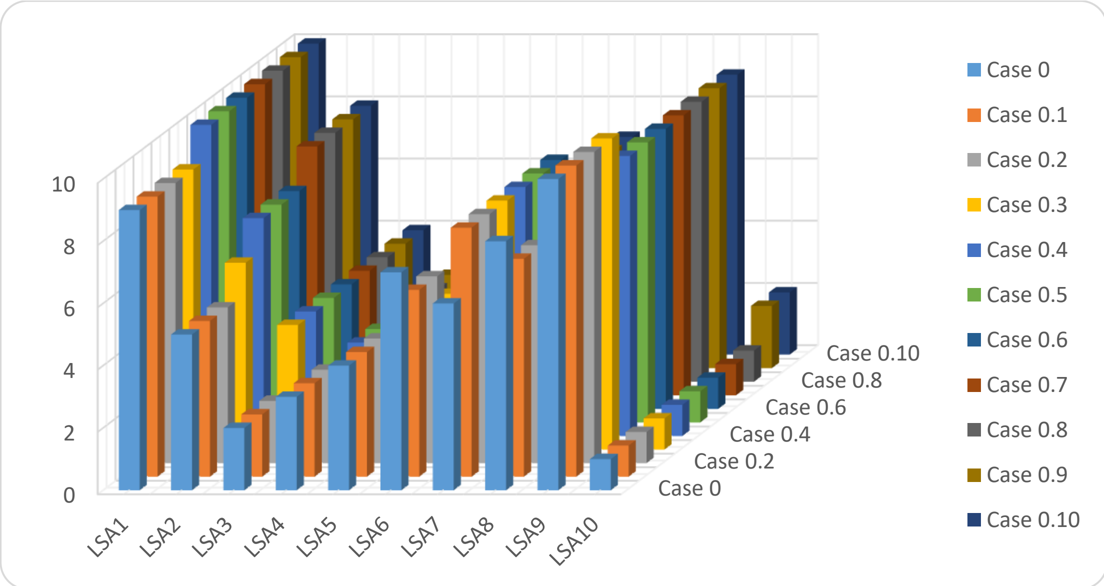

Figure 6. The rank of alternative under different values of β.

4 | Conclusions

This study suggested a decision-making model for livestock site selection in Egypt. This study used the MCDM methodology to deal with conflicting criteria in the evaluation process. The trapezoidal fuzzy set deals with uncertainty in the evaluation process. The WASPAS method is used to rank the alternatives. This study gathered 11 criteria and 10 alternatives. Three decision-makers and experts are invited to evaluate the requirements and options in this study. Three experts built the decision matrix using the trapezoidal fuzzy linguistic terms based on their opinions. Then, these variables are replaced by trapezoidal fuzzy numbers. Then, these matrices are combined to obtain one decision matrix. The results show that alternative 1 is the best and alternative 10 is the worst. A sensitivity analysis was conducted to show the rank of other options based on different results.

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Author Contribution

All authors contributed equally to this work.

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Data Availability

The datasets generated during and/or analyzed during the current study are not publicly available due to the privacy-preserving nature of the data but are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare that there is no conflict of interest in the research.

Ethical Approval

This article does not contain any studies with human participants or animals performed by any of the authors.

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