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An efficient Model for Selection of Unmanned Aerial Vehicles designed for Precision Agriculture

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Abstract

Precision agriculture (PA) utilizing unmanned aerial vehicles (UAVs) has supplanted labor-intensive and time-consuming conventional agricultural methods in recent times. This is because of its great economic benefits, as it possesses many advantages. It's fascinating to see how drones are being increasingly used in agriculture due to the numerous benefits they offer. However, it's important to evaluate their performance and determine the most effective criteria to ensure their optimal use. To make the most effective use of drones in agriculture, we need to consider multiple criteria when making decisions about their performance. The suggested model is constructed utilizing neutrosophic sets to effectively handle uncertainty and address multi-criteria decision-making (MCDM) situations with several competing criteria and options. The proposed model integrates Multi-Attributive Border Approximation Area Comparison (MABAC), and the entropy method is used for evaluating the performance of UAVs in PA based on diverse criteria and their importance, along with single-valued neutrosophic sets (SVNSs). The entropy method used for calculating the weight of criteria, and the MABAC method is used for ranking alternatives. An experimental case study has been established for choosing the best UAV for precision agriculture.

Keywords: Precision Agriculture; Unmanned Aerial Vehicles; MCDM; MABAC; Entropy; Neutrosophic Sets.

1 | Introduction

Precision agriculture (PA) is a revolutionary farming method that uses technology to improve operations and increase yield in recent years. Through the use of cutting-edge technologies for data collection and analysis, precision agriculture empowers farmers to make well-informed decisions and allocate resources exactly where and when they are needed. This focused strategy minimizes waste and lessens the impact on the environment by optimizing the use of pesticides, water, and fertilizers.

Unmanned aerial vehicles (UAVs) have emerged as a crucial tool in precision agriculture because they can swiftly and effectively gather high–resolution data. With their array of sensors and cameras, UAVs can take precise aerial photos of crops, soil, and other agricultural resources, where they can access the collected data that is used in precision agriculture[1]. They are also considered effective in monitoring changes occurring in agricultural fields and are also characterized by their low cost compared to satellites [2]. This data collected

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by UAVs can be examined afterward to help with decision-making about fertilization, irrigation, pest management, and general crop management. UAVs are also distinguished by their high ability to monitor crops, as they allow the discovery of many plants that may be obscured by terrain.Choosing the best UAV for a given situation entails assessing and contrasting several factors or characteristics. Therefore, choosing the best UAV for precision agriculture is a multi-attribute collective decision-making problem [3].

When choosing a UAV for precision agriculture, different stakeholders—such as agronomists, and technological experts—may have different goals and points of view. In order to tackle this issue, a methodical strategy is needed to assess and contrast UAVs using the established standards. When evaluating UAVs, there are frequently several factors to take into account, including dimensions, payload, and endurance [4].Thus, it is imperative to assess every criterion independently and together to understand the UAV's capabilities comprehensively. Certain criteria may be extra significant of needs than others, and not all criteria are created equal. So it is necessary to decide which criteria are critical to operations and adjust the evaluation's weighting accordingly. Therefore, Weighing the benefits and drawbacks of each criterion can help you decide whether trade-offs are acceptable [5], which a bigger UAV could be less agile than a smaller UAV but might have a longer flying period and a larger payload capacity. According to the above issues, evaluating UAVs for precision agriculture usage is a complicated MCDM challenge.

MCDM is one effective technique for using UAVs in PA which, a group of individuals or stakeholders use it to evaluate and select the best option from a set of options regarding to a number of qualities or criteria. In one particular study, ,the analytic hierarchy process (AHP) technique was used to prioritize objectives and select UAVs for operations involving several fleets, several studies used the Analytic Hierarchy Process to select the best UAV engines based on their technical attributes [6]. By using the AHP technique, the right type of UAV for crisis transport was determined [7]. The best single-engine piston airplane was determined using the AHP and Technique for Order of Preference by Similarity (TOPSIS) techniques [8]. The combination of fuzzy logic and the AHP technique led to the development of meteorological forecasting systems for UAVs [9]. A combined fuzzy MCDM strategy is built upon two important techniques. The fuzzy-weighted zero-inconsistency (FWZIC) method is the first technique used to determine the weight coefficients for the UAV criterion. The fuzzy decision by opinion score method (FDOSM), which is based on both individual and group decision making, is the second technique for selecting UAV alternatives [10].

Fuzzy sets are only able to handle situations that are either true or false; they cannot deal with uncertain scenarios. To address this limitation, intuitionistic fuzzy sets and interval value intuitionistic fuzzy sets have been introduced as a generalization of fuzzy sets. However, the intuitionistic fuzzy set is still unable to express the inconsistency and ambiguity of information, to tackle ambiguity and inconsistency. The concept of truth, falsity, and indeterminacy (T, I, and F) membership has been introduced for neutrosophic sets. This can help to overcome the problems associated with such data. One specific type of neutrosophic set is called a single-valued neutrosophic set (SVNSs).

All previous studies illustrate the usefulness and flexibility of MCDM approaches in evaluating various characteristics of UAV technology in the context of PA. By using MCDM techniques, one can make informed decisions by comparing different options founded on several factors, including cost, effectiveness, and sustainability. Currently, no complete study exists that offers a whole approach to evaluating the UAV requirements and then classifying and selecting UAVs for each precision agriculture category. Therefore, this research provides a solution to evaluate UAV standards and choose the best UAV for each category of precision agriculture.

In this paper, the evaluation of UAV used in precision agriculture is introduced as an MCDM problem with the neutrosophic sets, including Entropy, MABAC. The purpose of this research is to delve further into the topic of uncertainty and vagueness by utilizing neutrosophic technique on different linguistic sets and integrating it with MCDM using entropy and MABAC methods to determine the most suitable agriculture UAV that would result in increased productivity and sustainability in their operations. UAVs are employed in a wide range of applications, including mapping, precision farming, photography, inspection, and surveillance.

Various UAVs models have been developed to meet customer demands. These models have distinct dimensions, carry a diversity of sensors and payload capacities. There are three standards are frequently applied to estimate these various categories and associated UAV substitutes: dimensions, payload, and endurance.

- Payload: Precision agriculture requires the collection of accurate data regarding crops and also soil conditions. UAVs are commonly used for this purpose, but their payload capacity limits the type and amount of equipment they can carry. Payload capacity pertains to the greatest weight a UAV can carry during flight, with sensors, cameras, or other equipment. Larger UAVs with higher payload capacity can carry more advanced cameras or sensors to capture more precise measurements or detailed photos conversely, though, smaller UAVs with a smaller cargo capacity can only carry smaller equipment, which restricts the amount and quality of data they can collect. Therefore, it's crucial to consider a UAV's payload capacity when selecting equipment for precision agriculture applications. It's important to keep in mind that even within the same category of UAVs, for instance fixed-wing or rotary-wing, the payload capacity can differ among diverse models. Therefore, when selecting a UAV for precision agriculture applications, it's crucial to thoroughly evaluate the payload capacity of different UAV models [11].
- Endurance: when discussing the use of UAVs in agriculture, endurance refers to the amount of time a UAV can stay in the air using a single battery charge or fuel tank. Longer endurance is generally preferred in PA applications because it enables the UAV to face larger farming areas and collect more data, numerous factors can affect endurance, such as the weight and size of the UAV and the type of propulsion system being employed. The endurance of different UAV models should be compared carefully to guarantee that it can cover the required distance and gather the appropriate data before landing, charging, or refueling [12].
- Dimensions: when discussing UAVs for agricultural use, the dimension requirement pertains to the actual size of the UAV, including height, width, and length. The size of a UAV is crucial since it affects how readily it can go around obstructions like buildings, trees, and power lines. Smaller UAVs are typically easier to handle and may fly closer to the ground, enabling the collection of more precise data. They might, however, be less durable and able to carry less cargo. However, larger UAVs might be fewer agile and not capable to fly as close to the ground, even though they might be able to carry more payload and stay in the air longer. The size and configuration of the farmland that will be scanned are crucial factors to take into account when choosing a UAV for PA. Where, a UAV that is too small could not be able to cover a sufficient amount of ground effectively, while a UAV that is too big might not be able to maneuver through confined locations. The exact requirements of the farmer or agronomic and the kind of data that must be gathered will determine the optimal UAV dimensions [13]. The basic criteria for evaluating UAVs are as in Figure 1.

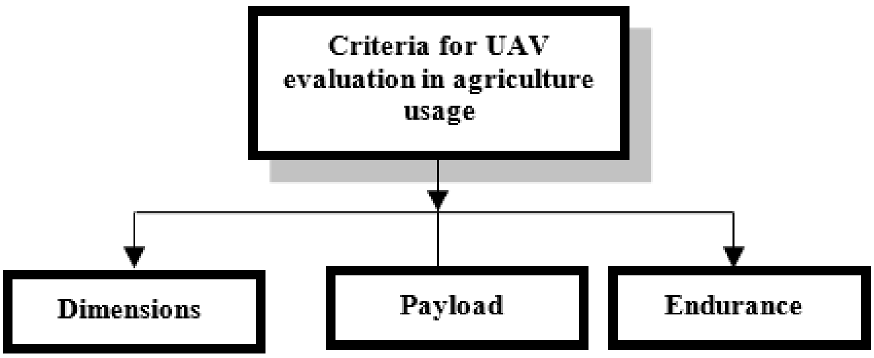

Figure 1. Criteria for UAV evaluation in PA.

UAV classification according to the type of wing (alternative) as in Figure 2:

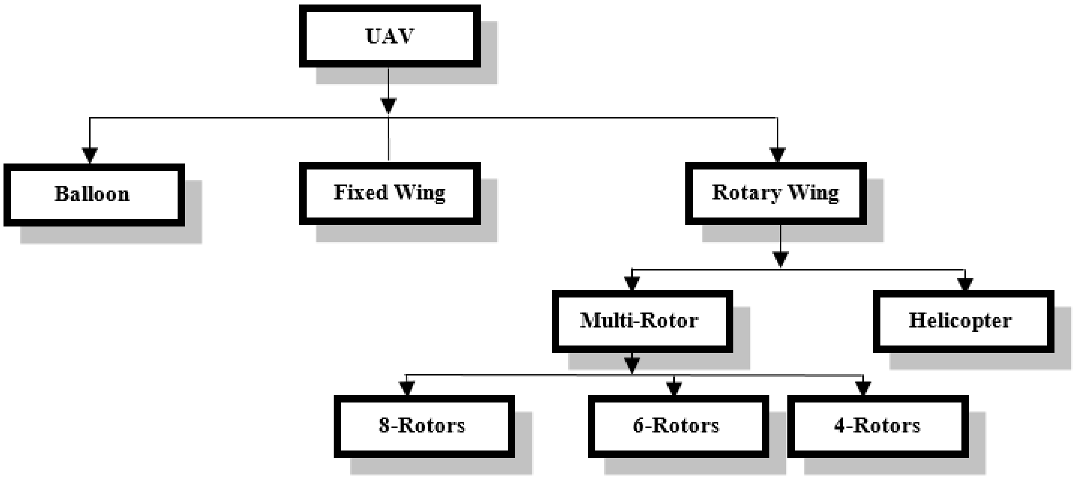

Figure 2. UAV classifications based on wing type.

In the agricultural field, UAVs can be divided into the following categories based on the number of rotors they have: fixed-wing and rotary-wing, which include helicopter and multi-rotary. Hybrid UAVs that combine earlier wing technologies have been eliminated from agricultural missions as they are not used. Fixed-Wing: Unmanned Aerial Vehicles (UAVs) are highly capable machines that can cover vast regions, travel long distances from the launch site, fly at high speeds and altitudes, and measure ground sample distance with centimeter-level accuracy. They are excellent resources for obtaining information about agricultural field surroundings quickly and accurately. For tasks that require heavier or denser payloads, fixed-wing UAVs are the best option due to their better endurance and payload capacity. They are particularly well-suited for tasks like pesticide spot spraying that require longer flight duration. They almost never need a pilot, and they can be controlled entirely on their own [14]. Table 1 lists the many kinds of fixed-wing UAVs that are part of this UAV group.

Table 1. kinds of fixed-wing UAVs.

Ref	Type	Description
[15]	GATEWING X100	Is a UAV intended for use in aerial mapping and surveying applications Is capable of being launched by hand and has a high-quality camera for taking pictures from the air. It has safety features including automated return-to-home and the ability to fly pre-programmed missions autonomously. Intended for a variety of mapping and aerial surveying uses in isolated or difficult-to-reach areas.
[16]	ZANGÃO UAV	designed for use in Portugal The characteristics and applications of drones may vary based on the manufacturer and intended purpose. Drones come in a wide range of sizes, designs, and capabilities.
[4]	M23UAV	It is suitable for tasks such as agricultural spraying and monitoring due to its ability to carry up to 200 kg of payload and last up to 390 minutes
[17]	TUFFWING MAPPER	produced by Tuff wing, a California-based drone manufacturer It comes with custom mapping software and a mapping camera capable of capturing visible, near-infrared photos, and high-resolution aerial imagery. Giving users the ability to swiftly create maps and models of sizable regions and carry out various data analysis operations.

Rotary-Wings: Multi-rotor and helicopters are aerial vehicles that use several rotors to create the necessary airflow and lift. One of their main advantages is their ability to hover, which is particularly useful for aerial photography as it allows for longer camera exposure times to compensate for low-light conditions. Multi-rotor aircraft have become more popular than helicopters due to their simpler mechanical structure, which only requires changing the speed of direct current motors for control. Multi-rotor UAV categorized into3 groups (8-rotors, 6-rotors, 4-rotors) each with its own set of specifications, discussed as shown in Table 2.

Table 2. Multi-rotor UAV categories.

Category	Type	Description	Ref
8-rotors	The MK OKTO XL 2	• this professional-grade octocopter drone for aerial photography and videography • It has a 25-minute flight duration • an 8kg cargo capacity • It has several features that are appropriate for professional photographers and filmmakers.	[18]
	OKTO XL	• comes equipped with a Canon G11 camera, which is ideal for aerial photography • It has a 25-minute flight duration • has a 1.8-kilogram payload capacity • Requires an observer to pilot it. • travels at a speed of 1 meter per second, at a height of 70 meters above the ground	[19]
	SPREADING WINGS S1000	• a high-quality professional drone that can be used for various purposes such as aerial photography, mapping, surveillance, and search and rescue missions • it has a maximum payload capacity of 6 kg and can fly for up to 15 minutes with its robust carbon fiber structure • can travel up to a range of 1.5 kilometers with a maximum speed of 80 km/h • has retractable landing gear, GPS, and remote control, making it a reliable device for taking aerial videos	[20]
6-rotors	EM6-800	• It is equipped with six electric motors, a robust carbon fiber frame • a maximum payload capacity of 5 kg • a maximum speed of 80 km/h and a range of up to 10 km • can fly for up to 50 minutes • It comes with retractable landing gear, GPS, and a remote control making it a dependable platform for taking aerial videos.	[21]
	DJI MATRICE 600	• Compared to a quadcopter, the DJI Matric 600 has a higher payload capacity • is less likely to experience the gyro effect • in case of a motor failure, it has a higher chance of landing safely	[22]

	HEXACOPTER P-Y6	• Has a strong motor system and a lightweight carbon fiber frame for steady flight performance. • has sophisticated flight control systems including GPS and altitude hold capabilities • Professionals in a variety of industries, such as construction, search and rescue, and agriculture	[23]
4-rotors	PARROTAR/ 2.0	• Can run on mobile or tablet operating systems. • has numerous sensors, including a 3-axis accelerometer, gyroscope, magnetometer, pressure sensor, and ultrasonic sensors to monitor ground and flying height • is equipped with four brushless in-runner motors that allow it to record video at 30 frames per second in 720p resolution	[24]
	PHANTOM2/ 3 PRO/4 PRO	• Are widely used by both professionals and enthusiasts for aerial photography and cinematography. • All versions have a gimbal to stabilize the camera and create smooth footage • The camera on the Phantom 2 has a 14-megapixel resolution, while the camera on the Phantom 3 has a 12-megapixel resolution.	[25]
	3DR IRIS/SOLO	• is designed for aerial photography and cinematography purposes • Is an affordable drone that is specifically made for aerial photography.	[26]
Helicopter	YAMAHA FAZER R	• use in commercial and industrial settings • designed to carry out tasks like agricultural spraying, surveying, and inspection • can run for up to three hours, allowing it to travel up to 100 kilometers in a single flight • With a maximum payload capacity of 20 kg.	[27]
	ROTOMOTIONSR200	• A top-of-the-line quadcopter drone designed for aerial mapping, inspection, and surveying • Boasts cutting-edge sensors and technologies that allow for precise and safe flight in various conditions. • With pre-programmed flight patterns, it can fly autonomously and carry a maximum payload of 5 kg • can navigate through complex areas with ease, thanks to its obstacle	[28]

Research conducted on the development of UAVs has some limitations. These include ineffective modeling of uncertainty, a lack of systematic determination of expert weights, failure to consider expert opinions, and failure to consider different types of criteria. In light of these limitations, we propose a new model that addresses these issues. The remaining portion of our manuscript is provided below for processing purposes. In section 2, the fundamental concepts of research methodology are introduced. In section 3, a case study for evaluating UAVs is solved to demonstrate the method's applicability. Also, the study's conclusions and recommendations for the future are presented in Section 4.

2 | Techniques

The research techniques used in this study was based on two MCDM approaches for estimating the UAVs used in PA applications. Entropy technique was presented to weigh the UAV estimation criteria across every category and MABAC technique to rank UAVs inside every agriculture category based on the weights obtained from Entropy. The framework of proposed methodology is as in Figure 3.

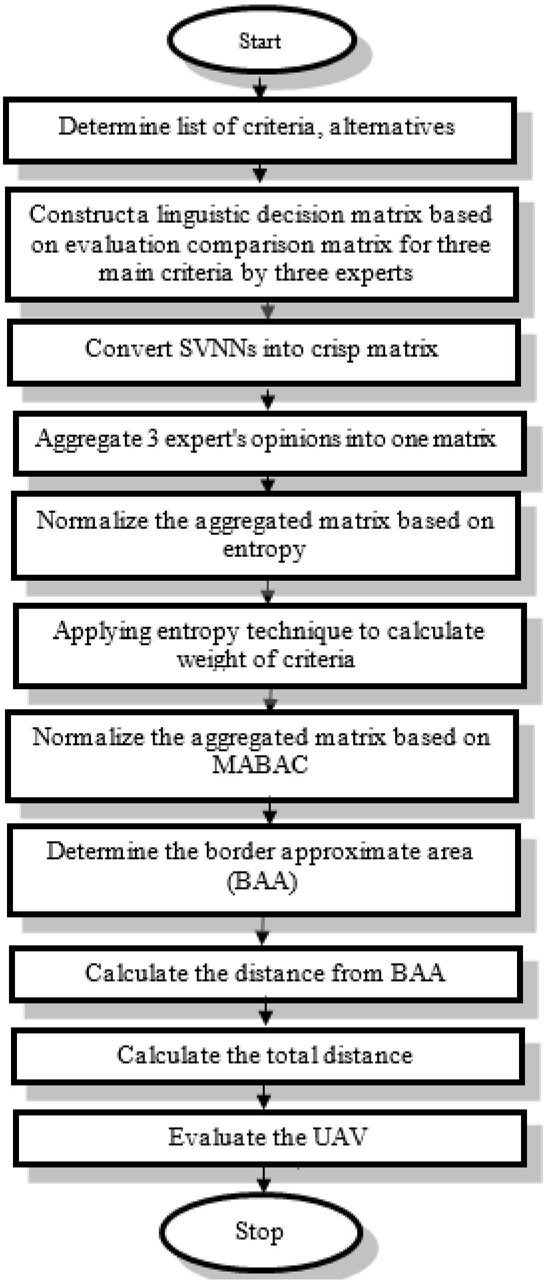

Figure 3. The Framework of proposed methodology.

2.1 | Entropy Technique

The MCDM approach was used to evaluate different options. Neutrosophic theory supports MCDM techniques to handle ambiguous situations and complex data. SVNS was applied, which helps determine the degree of uncertainty involved in evaluating linguistic representations of criteria and options. The primary advantage of the Entropy technique is it can be used in any weight-determination process. Thus, it is a helpful tool for decision-making difficulties.

Step 1. (Determined list of evaluation criteria): the process of evaluating UAVs involves the identification of decision-making criteria and defining the problem at hand. Firstly, the existing evaluation criteria were reviewed and clarified. Secondly, each criterion, sub-criterion, and relevant indicator was categorized based on its characteristics and the evaluation method used. Meanwhile, a team of experts evaluated the identified criteria to arrive at the chosen set of criteria for further assessment.

Step 2. (Expert/decision- maker respondents to a survey): A committee was formed to review the selection process for specialists in the field of unmanned aircraft devices, in which three experts were given the task of evaluating the judgment comparison for the main criteria using a single-valued neutrosophic scale, each with a different background in UAV design. We used a single-valued neutrosophic scale as in Table 3 to convert the linguistic scale into a corresponding numerical scale, using the terminology used by experts to construct decision matrices. The range of terms used in this context runs from "extremely good" to "extremely bad”. Each term in the language has a set of characteristics, including truth, indeterminacy, and falsity, collectively referred to as SVNS. These SVNS are then easily converted into a crisp, clear value for use in the suggested model. It should be noted that the score function (shown in Equation 1) is used to convert neutrosophic matrix into a crisp matrix [29]. This procedure enables more data-driven decision-making.

$$Score\ Function = \frac{2+(Tr-F-Id)}{3} \tag{1}$$

Where Tr, F, Id refers to truth, false, and indeterminacy respectively. This procedure made it possible for decision-makers to assess and prioritize the criteria objectively, enabling a more data-driven decision-making process. The experts then prioritized the criteria and eliminated the least significant ones resulting in a final list of criteria ranked by significance.

Table 3. Single-valued neutrosophic scale [29].

Variables of Linguistic	Abbreviation	SVNs		
		Tr	Id	F
Extremely Bad	EB	0.00	1.00	1.00
Very Very Bad	VVB	0.10	0.90	0.90
Very Bad	VB	0.20	0.85	0.80
Bad	B	0.30	0.75	0.70
Medium Bad	MB	0.40	0.65	0.60
Medium	M	0.50	0.50	0.50
Medium Good	MG	0.60	0.35	0.40
Good	G	0.70	0.25	0.30
Very Good	VG	0.80	0.15	0.20
Very Very Good	VVG	0.90	0.10	0.10
Extremely Good	EG	1.00	0.00	0.00

Step 3. (Aggregated decision matrix): Equation 2 is utilized to combine all these matrices into one matrix called aggregated matrix, after that Equation 3 is utilized to normalize the aggregated decision matrix based on entropy [30].

$$Y_{ij} = \frac{\sum_{j=1}^{N} q_{ij}}{N} \tag{2}$$

$$Norm_{ij} = \frac{y_{ij}}{\sum_{j=1}^{m} y_{ij}} \tag{3}$$

Where q_{ij} represents the value of criterion in matrix, N represents the number of experts, m represented the number of alternatives, $\sum_{j=1}^{m} y_{ij}$ shows the total of each criterion for each column in the aggregated matrix.

Step 4: We applied Entropy that represented by:

$$E_j = -h \sum_{i=1}^{m} Norm_{ij} * ln\, Norm_{ij} \quad , where\ h = 1/\,ln(m) \tag{4}$$

Step 5: Calculate weight vector by using:

$$W_j = \frac{1-E_j}{\sum_{j=1}^{n}(1-E_j)} \tag{5}$$

At the end of this stage, the weights of each criteria are obtained, which help in the process of evaluating the UAV. It is also necessary to give each of the alternatives a rank to help choose the best one according to each case study, this is what we will show in the next section.

2.2 | Multi Attribute Border Approximation Area Comparison (MABAC) Technique

MABAC is a precise and powerful MCDM technique that employs a systematic and straightforward computation approach. The MABAC steps to rank the UAV within each agriculture category based on the weights obtained from the entropy technique that was used before to select the best alternative are represented as follows:

Step 1: (Data input): As with any MCDM technique, any MCDM problem consists of a set of m alternatives denoted as $\{A1, A2, \dots . A_m\}$, and a set of n decision criteria denoted as $\{C1, C2, \dots . C_n\}$ with weighted vector w_i which we got from the entropy technique. These two elements are used to construct the decision matrix, an aggregated decision matrix that was constructed before is used, which serves as a tool to assess and rank a set of options according to a predefined set of criteria.

Step 2: Calculate normalized decision matrix:

$$d_{ij} = \frac{f_{ij}-\min(f_i)}{\max(f_i)-\min(f_i)} \; for\ beneficial\ criteria \tag{6}$$

$$d_{ij} = \frac{f_{ij} - \max(f_i)}{\min(f_i) - \max(f_i)} \; for\ non-beneficial\ criteria$$

where, f_{ij} refers to each alternative value regarding the determining criterion in the decision matrix.

Step 3: Calculate weighted normalized decision matrix:

$$b_{ij} = w_j x\,(d_{ij} + 1) \tag{7}$$

Where, w_j is the importance weight of decision variables.

Step 4: Calculate the border approximation area (BAA:)

$$g_i = \left(\prod_{i=1}^{m} b_{ij}\right)^{\frac{1}{m}} \tag{8}$$

$$G = [g_i]_n \tag{9}$$

Where, m is the number of alternatives.

Step 5: Calculate distance of alternatives from BAA:

$$Q = B - G \tag{10}$$

$$\begin{bmatrix} b_{11} - g_1 & b_{12} - g_2 & b_{13} - g_3 \\ \vdots & \dots & \vdots \\ b_{m1} - g_1 & \cdots & b_{mn} - g_n \end{bmatrix} = \begin{bmatrix} q_{11} & q_{12} & q_{1n} \\ \vdots & \dots & \vdots \\ q_{m1} & \cdots & q_{mn} \end{bmatrix}$$

$$S_i = \sum_{j=1}^{n} q_{ij}$$

Step 6: Selection of the best alternative with the highest rank.

3 | Result and Discussion

In our case study, the three main criteria and thirteen alternatives are proposed based on the ones introduced in [10]. Figure 1 shows how the three different classes of endurance, payload, and dimension can be used to separate the predetermined criteria for evaluating UAVs, as mentioned in step 2 in Entropy, data is gathered from experts. First off, a UAV panel consisting of three experts were given the task of evaluating the judgment comparison for the main criteria using a single-valued neutrosophic scale. Tables 4, 5 and 6 display the evaluation matrix for the three main criteria by three experts respectively. Tables 7- 9 show the outcome of converting the collected decisions for the importance level from a linguistic scale to a corresponding numerical scale based on a single-valued neutrosophic scale. Table 10, shows an aggregated decision matrix by normalization, which was calculated by using Equation (3). Table 11, shows a normalized decision matrix based on the entropy technique. In Table 12, we applied the Entropy technique to calculate weight of criteria. According to Table 12, the payload criterion was assigned the highest weight (0.404434) among the three main criteria, indicating its greater importance in comparison to the other criteria. The Dimension criterion was given the second highest weight (0.329404), while the Endurance criterion had the lowest weight (0.266161) as appear also in Figure 4.

Table 4. Evaluation comparison matrix for three main criteria by first expert.

	Alternative	Payload (kg)	Endurance (min)	Dimension (m)
A1	8 Rotors (The MK OKTO XL 2)	EG	G	MG
A2	8 Rotors (OKTO XL)	G	VVG	VG
A3	8 Rotors (SPREADING WINGS S1000)	M	VG	B
A4	6 Rotors (EM6-800)	MG	G	EG
A5	6 Rotors (DJI MATRICE 600)	VG	VVG	G
A6	6 Rotors (HEXACOPTER P-Y6)	B	VG	M
A7	4 Rotors (ParrotANAFI)	G	EG	G
A8	4 Rotors (PHANTOM2/3 PRO/4 PRO)	VVG	G	VVG
A9	4 Rotors (3DR IRIS/SOLO)	VG	M	VG
A10	Helicopter (YAMAHA FAZER R)	EG	G	EG
A11	Helicopter (ROTOMOTIONSR200)	G	VVG	G
A12	Fixed-wing (GATEWING X100)	M	VG	M
A13	Fixed-wing (ZANGÃO UAV)	B	VG	G

Table 5. Evaluation comparison matrix for three main criteria by second expert.

	Alternative	Payload (kg)	Endurance (min)	Dimension (m)
A1	8 Rotors (The MK OKTO XL 2)	MG	EG	G
A2	8 Rotors (OKTO XL)	VG	G	VVG
A3	8 Rotors (SPREADING WINGS S1000)	B	M	VG
A4	6 Rotors (EM6-800)	G	MG	EG
A5	6 Rotors (DJI MATRICE 600)	VVG	VG	G
A6	6 Rotors (HEXACOPTER P-Y6)	VG	B	M
A7	4 Rotors (ParrotANAFI)	EG	EG	G
A8	4 Rotors (PHANTOM2/3 PRO/4 PRO)	G	G	G
A9	4 Rotors (3DR IRIS/SOLO)	M	M	VVG
A10	Helicopter (YAMAHA FAZER R)	MG	G	EG
A11	Helicopter (ROTOMOTIONSR200)	VG	G	G
A12	Fixed-wing (GATEWING X100)	B	VVG	M
A13	Fixed-wing (ZANGÃO UAV)	B	VG	G

Table 6. Evaluation comparison matrix for three main criteria by third expert.

	Alternative	Payload (kg)	Endurance (min)	Dimension (m)
A1	8 Rotors (The MK OKTO XL 2)	MG	EG	G
A2	8 Rotors (OKTO XL)	VG	G	VVG
A3	8 Rotors (SPREADING WINGS S1000)	B	M	VG
A4	6 Rotors (EM6-800)	G	MG	EG
A5	6 Rotors (DJI MATRICE 600)	VVG	VG	G
A6	6 Rotors (HEXACOPTER P-Y6)	VG	B	M
A7	4 Rotors (ParrotANAFI)	EG	EG	G
A8	4 Rotors (PHANTOM2/3 PRO/4 PRO)	G	G	G
A9	4 Rotors (3DR IRIS/SOLO)	M	M	VVG
A10	Helicopter (YAMAHA FAZER R)	MG	G	EG
A11	Helicopter (ROTOMOTIONSR200)	VG	G	G
A12	Fixed-wing (GATEWING X100)	B	VVG	M
A13	Fixed-wing (ZANGÃO UAV)	B	VG	G

Table 7. Crisp decision matrix for 1st expert evaluation.

	Payload (kg)	Endurance (min)	Dimension (m)
A1	0.976667	0.716667	0.616667
A2	0.716667	0.0999	0.816667
A3	0.5	0.816667	0.283333
A4	0.616667	0.716667	0.976667
A5	0.816667	0.0999	0.716667
A6	0.283333	0.816667	0.5
A7	0.716667	0.976667	0.716667
A8	0.0999	0.716667	0.0999
A9	0.816667	0.5	0.816667
A10	0.976667	0.716667	0.976667
A11	0.716667	0.0999	0.716667
A12	0.5	0.816667	0.5
A13	0.283333	0.816667	0.716667

Table 8. Crisp decision matrix for 2nd expert evaluation.

	Payload (kg)	Endurance (min)	Dimension (m)
A1	0.616667	0.976667	0.716667
A2	0.816667	0.716667	0.0999
A3	0.283333	0.5	0.816667
A4	0.716667	0.616667	0.976667
A5	0.0999	0.816667	0.716667
A6	0.816667	0.283333	0.5
A7	0.976667	0.976667	0.716667
A8	0.716667	0.716667	0.716667
A9	0.5	0.5	0.0999
A10	0.616667	0.716667	0.976667
A11	0.816667	0.716667	0.716667
A12	0.283333	0.0999	0.5
A13	0.283333	0.816667	0.716667

Table 9. Crisp decision matrix for 3th expert evaluation.

	Payload (kg)	Endurance (min)	Dimension (m)
A1	0.616667	0.976667	0.716667
A2	0.816667	0.716667	0.0999
A3	0.283333	0.5	0.816667
A4	0.716667	0.616667	0.976667
A5	0.0999	0.816667	0.716667
A6	0.816667	0.283333	0.5
A7	0.976667	0.976667	0.716667
A8	0.716667	0.716667	0.716667
A9	0.5	0.5	0.0999
A10	0.616667	0.716667	0.976667
A11	0.816667	0.716667	0.716667
A12	0.283333	0.0999	0.5
A13	0.283333	0.816667	0.716667

Table 10. Aggregated matrix.

	Payload (kg)	Endurance (min)	Dimension (m)
A1	0.736667	0.89000033	0.68333367
A2	0.783333667	0.511078	0.33882233
A3	0.355555333	0.60555567	0.638889
A4	0.683333667	0.65000033	0.976667
A5	0.338822333	0.57774467	0.716667
A6	0.638889	0.461111	0.5
A7	0.890000333	0.976667	0.716667
A8	0.511078	0.716667	0.511078
A9	0.605555667	0.5	0.33882233
A10	0.736667	0.716667	0.976667
A11	0.783333667	0.511078	0.716667
A12	0.355555333	0.33882233	0.5
A13	0.283333	0.816667	0.716667
Sum	7.702124	8.27205833	8.33094733

Table 11. Normalized decision matrix based on Entropy.

	Payload (kg)	Endurance (min)	Dimension (m)
A1	0.095645	0.107591	0.082024
A2	0.101704	0.061784	0.04067
A3	0.046163	0.073205	0.076689
A4	0.08872	0.078578	0.117234
A5	0.043991	0.069843	0.086025
A6	0.08295	0.055743	0.060017
A7	0.115553	0.118068	0.086025
A8	0.066355	0.086637	0.061347
A9	0.078622	0.060444	0.04067
A10	0.095645	0.086637	0.117234
A11	0.101704	0.061784	0.086025
A12	0.046163	0.04096	0.060017
A13	0.036786	0.098726	0.086025

Table 12. Calculation of Entropy.

	Payload (kg)	Endurance (min)	Dimension (m)
A1	-0.22449	-0.23987	-0.20512
A2	-0.23246	-0.17201	-0.13024
A3	-0.14198	-0.19139	-0.19694
A4	-0.2149	-0.19988	-0.2513
A5	-0.13742	-0.18589	-0.21103
A6	-0.20651	-0.16093	-0.16884
A7	-0.24937	-0.25225	-0.21103
A8	-0.18	-0.21192	-0.17123
A9	-0.19994	-0.16961	-0.13024
A10	-0.22449	-0.21192	-0.2513
A11	-0.23246	-0.17201	-0.21103
A12	-0.14198	-0.13087	-0.16884
A13	-0.12149	-0.22859	-0.21103
$\sum_{i=1}^{m} Norm_{ij}$	-2.50749	-2.52714	-2.51815
$E_j = -h \sum_{i=1}^{m} Norm_{ij} * \ln Norm_{ij}$	0.9776	0.985258	0.981755
$W_j = \frac{1-E_j}{\sum_{j=1}^{n}(1-E_j)}$	0.404434	0.266161	0.329404

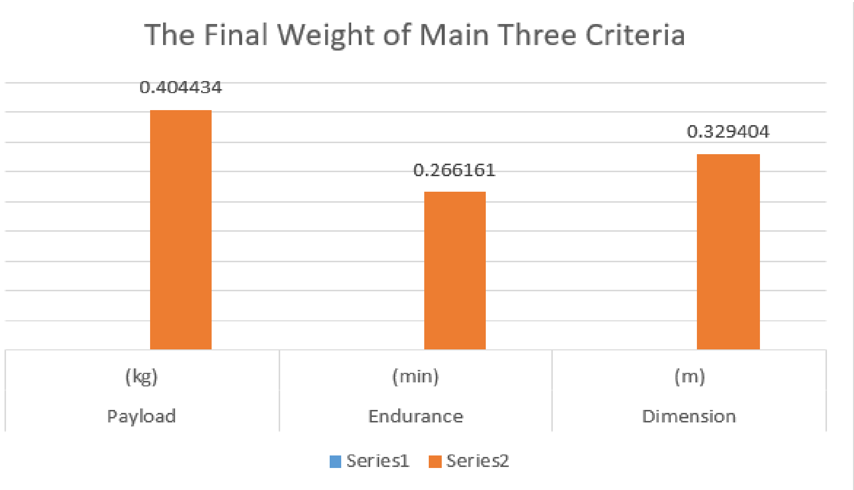

Figure 4. The Final weight of main three criteria.

In applying MABAC, start with aggregated decision matrix. The MABAC result as follows: Table 14 displays the normalized decision matrix (d_{ij}) obtained by applying equation 6 to the aggregated decision matrix in Table 13.Table 15 displays the calculated weighted normalized decision matrix using Equation 7. Here, w_i represents the weighted set of criteria that we obtained previously from the entropy technique. Table 16 shows the results obtained by applying equations 8 and 9 to obtain the border approximation area (BAA).By applying equation 10, we obtain the distance of alternatives from BBA, which is shown in Table 17. By applying equation 10, we obtain the distance of alternatives from BBA (q_{ij}), which is shown in Table 17. Also Table 17 displays the ranking of each alternative obtained through the MABAC technique.The analysis showed that the highest-ranked UAV is Helicopter (YAMAHA FAZER R) with a total distance value equal to (0.371597). The next highest-ranked UAV is 4 Rotors (ParrotANAFI)with a total distance value equal to (0.353474), while the lowest-ranked UAV is Fixed-wing (GATEWING X100)with a total distance value equal to (-0.30276).

Table 13. Decision matrix in MABAC technique.

Decision variable	Max	Max	Max
Weight from Entropy	0.404434	0.266161	0.329404
	Payload	Endurance	Dimension
	(kg)	(min)	(m)
A1	0.736667	0.89000033	0.68333367
A2	0.78333367	0.511078	0.33882233
A3	0.35555533	0.60555567	0.638889
A4	0.68333367	0.65000033	0.976667
A5	0.33882233	0.57774467	0.716667
A6	0.638889	0.461111	0.5
A7	0.89000033	0.976667	0.716667
A8	0.511078	0.716667	0.511078
A9	0.60555567	0.5	0.33882233
A10	0.736667	0.716667	0.976667
A11	0.78333367	0.511078	0.716667
A12	0.35555533	0.33882233	0.5
A13	0.283333	0.816667	0.716667

Table 14. Normalized decision matrix (d_{ij}) in MABAC technique.

Decision variable	Max	Max	Max
Weight from Entropy	0.168022	0.341668	0.49031
	Payload	Endurance	Dimension
	(kg)	(min)	(m)
A1	0.747253	0.864126	0.540118
A2	0.824176	0.270059	0
A3	0.119048	0.418179	0.470438
A4	0.659341	0.487859	1
A5	0.091466	0.374578	0.592377
A6	0.586081	0.191722	0.252691
A7	1	1	0.592377
A8	0.375403	0.592377	0.270059
A9	0.531136	0.252691	0
A10	0.747253	0.592377	1
A11	0.824176	0.270059	0.592377
A12	0.119048	0	0.252691
A13	0	0.749155	0.592377

Table 15. Weighted normalized decision matrix (b_{ij}) in MABAC technique.

Decision variable	Max	Max	Max
Weight from Entropy	0.168022	0.341668	0.49031
	Payload	Endurance	Dimension
	(kg)	(min)	(m)
A1	0.293577	0.636912	0.755135
A2	0.306502	0.433939	0.49031
A3	0.188025	0.484546	0.72097
A4	0.278806	0.508354	0.98062
A5	0.18339	0.469649	0.780758
A6	0.266497	0.407173	0.614207
A7	0.336044	0.683336	0.780758
A8	0.231098	0.544064	0.622723
A9	0.257265	0.428004	0.49031
A10	0.293577	0.544064	0.98062
A11	0.306502	0.433939	0.780758
A12	0.188025	0.341668	0.614207
A13	0.168022	0.59763	0.780758

Table 16. Calculated Border pproximation Area (BAA) in MABAC technique.

Decision variable	Max	Max	Max
Weight from Entropy	0.168022	0.341668	0.49031
	Payload	Endurance	Dimension
	(kg)	(min)	(m)
A1	0.293577	0.636912	0.755135
A2	0.306502	0.433939	0.49031
A3	0.188025	0.484546	0.72097
A4	0.278806	0.508354	0.98062
A5	0.18339	0.469649	0.780758
A6	0.266497	0.407173	0.614207
A7	0.336044	0.683336	0.780758
A8	0.231098	0.544064	0.622723
A9	0.257265	0.428004	0.49031
A10	0.293577	0.544064	0.98062
A11	0.306502	0.433939	0.780758
A12	0.188025	0.341668	0.614207
A13	0.168022	0.59763	0.780758
g_i	0.247525	0.492337	0.706803

Table 17. Distance of the alternative from the BAA (q_{ij}) in MABAC Technique.

Decision variable	Max	Max	Max	S_i	Ranking
Weight from Entropy	0.168022	0.341668	0.49031		
	Payload (kg)	Endurance (min)	Dimension (m)		
A1	0.046052	0.144575	0.048333	0.23896	4
A2	0.058977	-0.0584	-0.21649	-0.21591	11
A3	-0.0595	-0.00779	0.014168	-0.05312	9
A4	0.031281	0.016017	0.273817	0.321115	3
A5	-0.06413	-0.02269	0.073956	-0.01287	7
A6	0.018972	-0.08516	-0.0926	-0.15879	10
A7	0.088519	0.190999	0.073956	0.353474	2
A8	-0.01643	0.051727	-0.08408	-0.04878	8
A9	0.00974	-0.06433	-0.21649	-0.27109	12
A10	0.046052	0.051727	0.273817	0.371597	1
A11	0.058977	-0.0584	0.073956	0.074534	6
A12	-0.0595	-0.15067	-0.0926	-0.30276	13
A13	-0.0795	0.105293	0.073956	0.099746	5

The S_i values of alternatives are as in Figure 5.

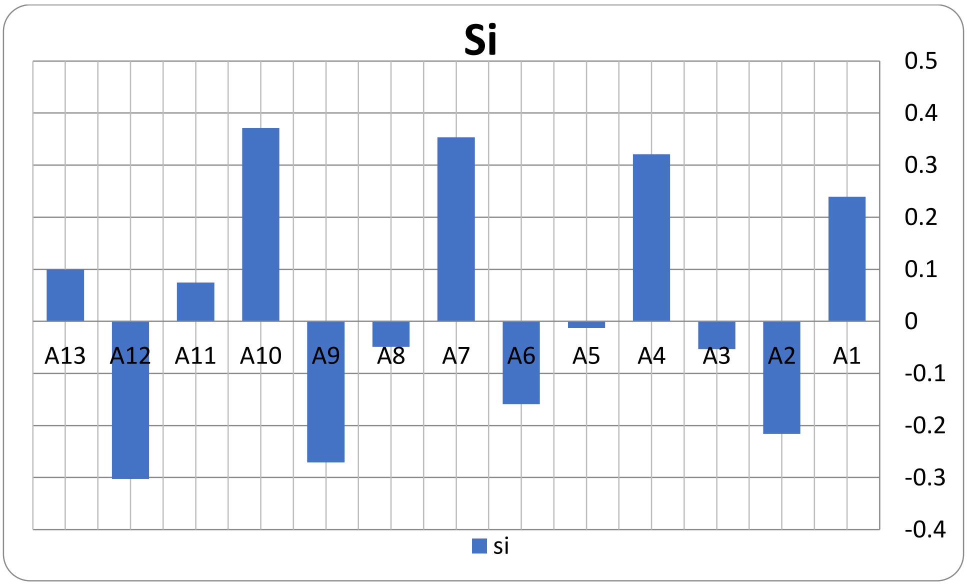

Figure 5. S_i Values of alternatives.

4 | Conclusion

The study's contribution to precision agriculture is significant in increasing production and efficiency by utilizing technologies like drones and UAVs. By choosing the appropriate UAVs for particular agricultural jobs, such pesticide spraying or crop monitoring, farmers may optimize their operations and get better results. Unmanned Aerial Vehicles (UAVs) can be categorized into five main types, each having unique characteristics: those that possess eight, six, or four rotors, helicopters, and fixed wings. UAVs with eight rotors are known for their stability and have the ability to carry a large payload, making them appropriate for heavy-duty farming tasks such as fertilizer and pesticide spraying. Farmers, agricultural businesses, and research institutes can benefit from the suggested estimation and choosing approach for precision agriculture. Lastly, using entropy and MABAC methods can help agricultural decision-makers make better decisions and achieve more precise results in UAV estimation for PA.

In conclusion, the research is to expand on the discussion of uncertainty and vagueness issues by using neutrosophic technique on various linguistic sets by integrating it with MCDM using entropy and MABAC methods.

In the future, we will use various MCDM techniques such as ANP and SMART for evaluating UAVs.

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Author Contributaion

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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