Journal of Research in Business : 9(2), 395-421 December • Dezember • Aralık: 2024 • ISSN: 2630-6255
DOI: 10.54452/jrb.1447602

RESEARCH ARTICLE • FORSCHUNGSARTIKEL • ARAŞTIRMA MAKALESİ

DRONE SELECTION FOR AGRICULTURAL ENTERPRISES WITH INTERVAL TYPE-2 FUZZY COPRAS METHOD

ARALIKLI TİP-2 BULANIK COPRAS YÖNTEMİ İLE TARIM İŞLETMELERİ İÇİN DRON SEÇİMİ

Alparslan OĞUZ[*]

Abstract

Technological advancements have led to changes in unmanned aerial vehicles, just as in all fields. These vehicles, known as drones, are used in many areas such as mapping, logistics, entertainment, and agriculture. Especially in agriculture, drones are widely used for various purposes such as mapping, detecting weeds, fertilization, and spraying. This situation has increased the market volume of drones and many companies have introduced their products for sale. Agriculture plays a significant role in the development of developing countries, and drone technologies are of great importance in increasing sector productivity. Drone technologies provide transparency and traceability in the cultivation process of products. Therefore, the aim of the study is to determine the selection criteria of agricultural drones for agricultural enterprises and to select the most suitable alternative among the alternatives. Nine criteria were determined through literature review and expert opinion. Seven alternatives from two companies selling in Türkiye were evaluated. Alternatives were analyzed using the Interval Type-2 COPRAS method. As a result of the evaluation by three experts, alternative A2 was determined as the most suitable alternative.

Key Words: Drone selection, interval type-2 fuzzy sets, COPRAS
JEL Classification: M1, Q16

Öz

Teknolojik gelişmeler tüm alanlarda olduğu gibi insansız hava araçlarında da değişimlere neden olmuştur. Dron olarak adlandırılan bu araçlar harita, lojistik, eğlence ve tarım gibi birçok alanda kullanılmaktadır. Özellikle tarım alanlarında haritalama, yabani otların tespiti, gübreleme ve ilaçlama gibi çeşitli amaçlarla yaygın olarak kullanılmaktadır. Bu durum, dron pazar hacmini artırmış ve birçok firmanın ürünleri satışa sunulmuştur. Tarım, özellikle gelişmekte olan ülkelerin kalkınmasında önemli bir rol oynamaktadır. Sektör verimliliğinin artırılmasında dron teknolojileri büyük önem taşımaktadır. Dron teknolojileri ürünlerin

---

[*] **Corresponding Author:** Assist. Prof. Dr., Erzincan Binali Yıldırım University, Kemah Vocational School, Office Services and Secretarial Department, aoguz@erzincan.edu.tr, ORCID: 0000-0003-1920-5674.

To cite this article: Oğuz, A. (2024). Drone selection for agricultural enterprıses with interval type-2 fuzzy COPRAS method. *Journal of Research in Business, 9*(2), 395-421. DOI: 10.54452/jrb.1447602

Ethics Committee: Erzincan Binali Yıldırım University, Human Research Social and Humanities Ethics Committee, 23.06.2023, 06-18.

Submitted: 05.03.2024 **Revised:** 17.07.2024
Accepted: 22.07.2024 **Published Online:** 06.12.2024

yetiştirilme sürecinde şeffaflık ve izlenebilirlik sağlamaktadır. Bu nedenle çalışmada tarım işletmelerinin dron seçim kriterlerinin belirlenmesi ve alternatifler arasından en uygun olanın seçimi amaçlanmıştır. Literatür taraması ve uzman görüşü ile dokuz kriter belirlenmiştir. Türkiye'de satışı bulunan iki firmaya ait yedi alternatif değerlendirilmiştir. Alternatifler, Aralıklı Tip-2 COPRAS yöntemi ile analiz edilmiştir. Üç uzmanın değerlendirmesi sonucu A2 alternatifi en uygun alternatif olarak belirlenmiştir.

Anahtar Kelimeler: Dron seçimi, aralıklı tip-2 bulanık kümeler, COPRAS

JEL Sınıflandırılması: M1, Q16

1. Introduction

In the last century, rapid population growth and urbanization have increased the demand for food. Ensuring food security for the current world population of seven billion is a challenging process. Considering the rate of population growth, agricultural production needs to be increased by 70% to be sufficient. On the other hand, factors such as soil erosion, improper land use, unbalanced fertilization and irrigation, improper crop rotation, and deforestation are reducing agricultural production. Additionally, climate change, leading to a decrease in available water resources and agricultural land, threatens food security (Ercan et al., 2019; Kılavuz & Erdem, 2019). Correcting these adverse conditions with traditional farming practices seems difficult. Therefore, agricultural enterprises need to use modern agricultural techniques and technologies. In this context, Industry 4.0 applications have begun to be implemented by agricultural enterprises.

The digitization of agriculture has affected the sector in many ways. Through digital farming applications, agricultural machinery and equipment have been equipped with sensors, and an Internet of Things infrastructure has been established. These connected devices provide real-time data on parameters such as plant water stress, mineral and fertilizer needs, soil condition, weather conditions, pest control, and harvest timing (Kılavuz & Erdem, 2019). These data reduce uncertainties in agricultural operations such as water availability, weather conditions, crop productivity, and thus increase production efficiency.

When examining global agricultural data, China ranked first in agricultural production with a 32% share in 2021. The United States ranked second. 80% of farmers in the United States use agricultural technologies. Netherlands, Taiwan, and Israel have achieved high yields in small agricultural areas using agricultural technologies. The continent with the lowest agricultural productivity is Africa (TBB, 2023). Considering these values, it can be stated that countries combining agriculture with technology achieve more efficient production. In developing countries, the share of agriculture in gross domestic product is higher compared to developed countries. Therefore, increasing productivity with digital technologies in agriculture is important for national incomes. In Türkiye, while direct agricultural product exports were 8.3 billion dollars in 2022, imports were 10.6 billion dollars. While the share of agriculture in GDP is 4.8% worldwide, this rate was 5.8% in Türkiye (TBB, 2023). Therefore, it is important for agricultural enterprises in developing countries to use digital technologies both to reduce the trade deficit and to increase income levels.

In recent years, aerial vehicles have been frequently used in agriculture due to developments in digitization of agriculture. Especially, advancements in communication and battery technology have enhanced the capabilities of unmanned aerial vehicles and expanded their areas of use. These aircraft, also known as drones, are remotely controlled aerial vehicles. Initially, drones were used for military purposes by the United States and Japan. However, they have now become widespread in both the public and private sectors, creating a growing market for themselves. Drones, becoming increasingly accessible and affordable, are used in many fields such as journalism, sports, travel, marketing, agriculture, cargo delivery, racing, health, mapping, fashion, emergency aid, and communication (Ntalakas et al., 2017; Arslan & Delice, 2020).

Drones have been categorized over time based on technical, software, and hardware aspects, depending on their intended use. Depending on the users, a drone can be used for satellite connection in mapping, payload capacity in product delivery, flight range in military purposes, and image capture in personal use. Similar expectations are undoubtedly valid for drones used in agriculture as well. The use of drones in agriculture will create the infrastructure for data to be used in smart agriculture. Thus, detection of diseases and pests, water stress detection, yield/ripeness estimation, identification of weed flora, control of water resources, and monitoring of workers based on remote sensing and plant monitoring techniques can be achieved. Therefore, drone technologies provide traceability and transparency throughout the entire process of product cultivation (Türkseven et al., 2016). Agricultural drones are also used for spraying and fertilizing crops. These types of drones provide significant contributions in areas with high terrain slope, where other agricultural machinery cannot enter due to large plant sizes, or in rapid spraying and fertilization of large areas. This situation paves the way for the proliferation of agricultural drones and leads many producers to position themselves in the market with different models. Additionally, when drones are used with renewable energy, they contribute to sustainable agriculture through lower carbon emissions compared to agricultural tools consuming fossil fuels.

The selection of agricultural drones by users can be evaluated based on many criteria. Similar to other types of drones, criteria such as flight time, flight range, and communication ability are decisive factors. However, agricultural drones have specific criteria such as storage volume, spraying capability, and operational efficiency. The presence of many alternatives and criteria creates a selection problem for users. Supplier evaluation and selection problem can be considered as a Multi Criteria Decision Making (MCDM) problem since it includes some alternatives evaluated according to certain criteria (Ho et al., 2010). The aim of the study is to determine the most suitable among agricultural drone alternatives. Agricultural activity type should be taken into account when choosing a drone. The drone selection problem contains a certain degree of uncertainty arising from the personal views of the decision-maker and the linguistic variables used to express them. Therefore, fuzzy sets have been included in the study.

Fuzzy set theory is the most common method used to deal with uncertainty in MCDM problems (Mardani et al., 2015). Type-2 Fuzzy Sets (T2FS) are an extension of ordinary fuzzy sets proposed by Zadeh (1975). T2FS are quite flexible in modeling uncertainty in the presented information since their membership values are also fuzzy sets. As the uncertainty and imprecision of the information obtained increase due to the increase in the number of experts, T2FS are more flexible compared to Type-1 Fuzzy Sets (T1FS) (Ghorabaee et al., 2017; Mohamadghasemi et al., 2020). The main feature of T2FS is its ability to handle uncertainties more appropriately than T1FS. This is possible only when there are more parameters and more degrees of freedom in T2FS. Therefore, Interval Type-2 Fuzzy Sets (IT2FS) were used in this study to express decision-makers' uncertainties more accurately (Paksoy & Öztürk, 2019: 117). IT2FS is a special case of T2FS commonly used in MCDM problems (Mohammadi et al., 2017). In this study, an integrated model based on IT2FS and Complex Proportional Assessment (COPRAS) method was proposed for the selection of agricultural drones. For this purpose, some steps of the COPRAS method and arithmetic operations of IT2FS were used to evaluate drone alternatives. Seven alternatives from two drone manufacturers currently sold in Türkiye were included in the study.

The rest of the study is organized as follows. In the second section, MCDM methods with IT2FS and literature on drone selection are summarized. The proposed methodology is explained in detail in the third section. In the fourth section, the proposed model is applied to the drone selection problem. Sensitivity analysis is conducted in the fifth section, and analysis results are compared with different MCDM methods. In the final section, conclusions are discussed, and suggestions for future studies are presented.

2. Literature Review

Digitization has led to an increase in the utilization of drone technology across various sectors, including agriculture. This trend has elevated the usage of drones in agricultural operations, akin to its impact in other domains. Selecting the most suitable drone from the array of available options poses a MCDM problem for agricultural enterprises. MCDM is a significant branch of decision-making focusing on discrete decision spaces where decision alternatives are predefined (Triantaphyllou, 2000). In a drone selection problem, various perspectives such as costs, technical specifications, and availability need to be considered. Each perspective in MCDM is represented by a different criterion, and alternatives are evaluated based on these criteria, allowing decision-makers to incorporate diverse aspects into the decision-making process (Öztayşi, 2015).

In this study, T2FS are employed. The concept of T2FS, an extension of T1FS, was developed by Zadeh. T2FS offers significant advantages over traditional fuzzy sets in terms of providing more precise and robust results while encompassing uncertainties and vagueness. However, it should be noted that T2FS entails more computations and formulas alongside its positive aspects (John & Coupland, 2007; Aksoy et al., 2015; Kaya & Ayçin, 2021). Specifically, IT2FS, a specialized form of T2FS, are utilized in this study. In the literature, there are numerous studies demonstrating the integration of IT2FS with MCDM techniques in situations involving uncertainty and ambiguity. Some information regarding studies conducted in this context is presented in Table 1.

Table 1: Examples of Studies Conducted with Interval Type-2 Fuzzy Numbers

Author	Year	Method	Topic
Ghorabaee et al.	2014	Interval Type-2 Fuzzy COPRAS	Supplier selection
Ghorabaee et al.	2017	Interval Type-2 Fuzzy EDAS	Supplier evaluation
Ighravwea ve Babatunde	2018	Interval Type-2 Fuzzy CRITIC TOPSIS	Business model selection
Çalık	2019	Interval Type-2 Fuzzy TOPSIS	Contractor selection
Mohamadghasemi et al.	2020	Interval Type-2 Fuzzy FWA ELECTRE	Equipment selection
Vatansever ve Tellioğlu	2020	Interval Type-2 Fuzzy TOPSIS	Supplier selection
Dorfeshan et al.	2021	Interval Type-2 Fuzzy ARAS	Project selection
Ecer	2021	Interval Type-2 Fuzzy AHP	Green supplier selection
Sen et al.	2021	Interval Type-2 Fuzzy AHP-ARAS	Machine selection
Hoseini et al.	2021	Interval Type-2 Fuzzy BWM TOPSIS	Flexible supplier selection
Celik et al.	2021	Interval Type-2 Fuzzy BWM-TODIM	Green supplier selection
Kaya ve Aycin	2021	Interval Type-2 Fuzzy AHP – COPRAS-G	Supplier selection
Karagöz et al.	2021	Interval Type-2 Fuzzy ARAS	Facility location selection
Aka	2022	Interval Type-2 Fuzzy TOPSIS	Critical Success Factor
Yıldız et al.	2022	Interval Type-2 Fuzzy AHP	Company selection

Table 1 presents various selection and evaluation studies using IT2FS with MCDM techniques. Although the literature has matured with respect to product, machine, or supplier selection problems, in this study, the problem of drone selection is addressed through the lens of MCDM. While there are studies on drone selection using MCDM techniques, they are relatively few. Arslan & Delice (2020) employed the KEMIRA-M method for selecting personal drones. They compared six different drones based on twelve criteria, both internal and external. The most important alternatives were determined to be the camera and usability. Rakhade et al. (2021) investigated the selection of the most suitable agricultural drone. They identified ten criteria under functional, economic, and technical main categories. These criteria were analyzed using the AHP weighting and TOPSIS ranking methods, with real numbers assigned to the drones. Nur et al. (2021) evaluated drones used in last-mile delivery based on five main criteria: physical, performance, economic, environmental, and payload capacity. They identified four different types of drones as alternatives and conducted the analysis using an interval-valued intuitionistic fuzzy number-based TOPSIS method. Khan et al (2021) ranked twenty-seven drones based on criteria such as price, distance, and flight time using the AHP-TOPSIS method. In the literature, the criteria used for drone selection are shown in Table 2.

Table 2: Drone Criteria Present in the Literature

Author	Criteria
Arslan & Delice (2020)	Camera, control range, flight time, weight, price, aesthetics
Nur et al. (2020)	Physical features: Drone size, weight, drone type, fuel type Performance features: Internal computing components, location and proximity accuracy, communication and data quality, traceability and reliability Economic features: Repair cost, total unit cost, total lifecycle cost, operating cost, training cost Environmental: Adaptability, charging/fueling location, environmental impact, required delivery distance Payload capacity: Maximum flight time, total charge/fuel time, charge/fuel usage rate, maximum payload, maximum carrying dimensions, maximum attainable altitude, drone speed, dynamic assignment compatibility, package carrying flexibility, delivery flexibility
Rakhade et al. (2021)	Functional outputs: Flight time, spraying capacity, flight speed, spraying width Economic evaluation: Product cost, operating cost Technical inputs: Battery, control range, motor specifications, aircraft body
Merkepçi et al. (2021)	Weight, size, price, battery, maximum speed, camera, flight range, flight time, obstacle sensor, crash protection, automatic return to home, automatic route tracking, fixed altitude.

Studies on agricultural drones in the literature are primarily focused on drone usage (Ahirwar et al., 2019; Dutta & Goswami, 2020; Özgüven et al., 2022), their spraying capabilities (Mogili & Deepak, 2018; İnan & Karcı, 2021; Alkan & Ertuğrul, 2022; Özyurt et al., 2022), pollination (Yangal et al., 2022), and mapping (Puri et al., 2017).

Moreover, it has been observed that MCDM techniques have been employed in drone selection in recent years. While some studies have used real values (Rakhade et al., 2021; Khan et al., 2021), others have used fuzzy numbers (Nur et al., 2021). There are significant differences between the current study and previous literature. Firstly, the study employs newly proposed criteria not used in the literature. The criteria of safety, operational efficiency, and spraying speed were introduced for the first time based on expert opinions in this study. Additionally, the incorporation of expert opinions into the process using fuzzy numbers and the use of IT2FS in drone selection were realized in this study. Furthermore, the study contributes to the expansion of the existing IT2FS-based MCDM literature by addressing the product-equipment selection problem.

3. Methodology

In this section, IT2FS are defined, and their mathematical formulas are provided. The steps of the COPRAS method used for ranking alternatives are outlined.

3.1. Interval Type-2 Fuzzy Numbers

T2FS is one of the primary extensions of T1FS. T2FS are represented by primary and secondary membership values and can be beneficial in various fields, including decision-making theory. This section introduces the fundamental concepts and arithmetic operations of such fuzzy sets.

Definition 1. A T2FS is defined by a membership function denoted by $\tilde{\tilde{A}}$ in Equation 1 (Mendel et al., 2006):

$$\tilde{\tilde{A}} = \int_{x \in X} \int_{u \in J_x} \mu_{\tilde{\tilde{A}}}(x,u) / (x,u) \tag{1}$$

Where, X denotes the domain of , $\tilde{\tilde{A}}$. $\mu_{\tilde{\tilde{A}}}$ represents the membership function (secondary membership function) of $\tilde{\tilde{A}}$. $J_x \subseteq [0,1]$ denotes the primary membership function, while $\int \int$ expresses unity over all acceptable x and u. $\widehat{A}$. T2FS is referred to as an interval IT2FS for which all $\mu_{\tilde{\tilde{A}}}(x,u) = 1$ for $\tilde{\tilde{A}}$. Figure 1 provides an example of a trapezoidal IT2FS (Chen & Lee, 2010).

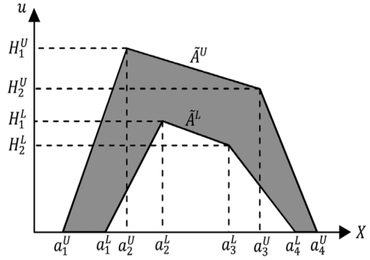


Figure 1: Example of a Trapezoidal Interval Type-2 Fuzzy Set

Definition 2. When both upper and lower membership functions of an IT2FS are trapezoidal fuzzy sets, it is referred to as a trapezoidal IT2FS. A trapezoidal IT2FS is expressed as $\tilde{\tilde{A}}$ in Equation 2 (Chen & Lee, 2010):

$$\tilde{\tilde{A}} = \left(\tilde{A}^T \middle| T \in \{U, L\}\right) = \left(a_j^T; H_{1A}^T; H_{2A}^T \middle| T \in \{U, L\}, j = 1,2,3,4\right) \tag{2}$$

Where, $\tilde{A}^U$ and $\tilde{A}^L$ represent, respectively, the upper and lower membership functions of $\tilde{\tilde{A}}$. $H_j^U \in [0,1]$ and $H_j^L \in [0,1]$ $(j = 1,2)$ denote the membership values corresponding to the elements a_{j+1}^U and a_{j+1}^L respectively.

Definition 3. Let $\tilde{\tilde{A}}$ and $\tilde{\tilde{B}}$ be two trapezoidal IT2FSs as shown in Equations 3-4, and let d be a real number.

$$\tilde{\tilde{A}} = \left(\tilde{A}^T \middle| T \in \{U, L\}\right) = \left(a_j^T; H_{1A}^T; H_{2A}^T \middle| T \in \{U, L\}, j = 1,2,3,4\right) \tag{3}$$

$$\tilde{\tilde{B}} = \left(\tilde{B}^T \middle| T \in \{U, L\}\right) = \left(b_j^T; H_{1B}^T; H_{2B}^T \middle| T \in \{U, L\}, j = 1,2,3,4\right) \tag{4}$$

For IT2FSs, arithmetic operations are defined as shown in Equations 5-10 (Ghorabaee et al., 2016):

Addition:

$$\tilde{\tilde{A}} \oplus \tilde{\tilde{B}} = (a_i^T + b_i^T ; min(H_{1A}^T ; H_{1B}^T), min(H_{2A}^T ; H_{2B}^T)\big| \, T \in \{U, L\}, i = 1{,}2{,}3{,}4) \tag{5}$$

$$\tilde{\tilde{A}} + d = (a_i^T + d; H_{1A}^T ; H_{2A}^T \big| T \in \{U, L\}, i = 1{,}2{,}3{,}4) \tag{6}$$

Subtraction:

$$\tilde{\tilde{A}} \ominus \tilde{\tilde{B}} = (a_i^T + b_{5-i}^T ; min(H_{1A}^T ; H_{1B}^T), min(H_{2A}^T ; H_{2B}^T)\big| T \in \{U, L\}, i = 1{,}2{,}3{,}4) \tag{7}$$

Multiplication:

$$\tilde{\tilde{A}} \otimes \tilde{\tilde{B}} = (X_i^T ; min(H_{1A}^T ; H_{1B}^T), min(H_{2A}^T ; H_{2B}^T)\big| T \in \{U, L\}, i = 1{,}2{,}3{,}4) \tag{8}$$

$$X_i^T = \begin{cases} min(a_i^T b_i^T , a_i^T b_{5-i}^T , a_{5-i}^T b_i^T , a_{5-i}^T b_{5-i}^T) \; if \; i = 1{,}2 \\ mak(a_i^T b_i^T , a_i^T b_{5-i}^T , a_{5-i}^T b_i^T , a_{5-i}^T b_{5-i}^T) \; if \; i = 3{,}4 \end{cases} \tag{9}$$

$$d.\tilde{\tilde{A}} = \begin{cases} (d.a_i^T ; H_{1A}^T , H_{2A}^T \big| T \in \{U, L\}, i = 1{,}2{,}3{,}4) \; if \; d \geq 0 \\ (d.a_{5-i}^T ; H_{1A}^T , H_{2A}^T \big| T \in \{U, L\}, i = 1{,}2{,}3{,}4) \; if \; d \leq 0 \end{cases} \tag{10}$$

Definition 4. The crisp value of a trapezoidal IT2FS is defined as shown in Equation 9 (Ghorabaee, 2015).

$$6\left(\tilde{\tilde{A}}\right) = \frac{1}{2}\left(\sum_{T \in \{U,L\}} \frac{a_1^T + (1 + H_{1A}^T)a_2^T + (1 + H_{2A}^T)a_3^T + a_4^T}{4 + H_{1A}^T + H_{2A}^T} \right) \tag{11}$$

Definition 5. $\mathcal{Z}\left(\tilde{\tilde{A}}\right)$ is defined as a function that finds the maximum between a trapezoidal IT2FS fuzzy number and zero.

$$\mathcal{Z}\left(\tilde{\tilde{A}}\right) = \begin{cases} \tilde{\tilde{A}} \; if \; 6\left(\tilde{\tilde{A}}\right) > 0 \\ \tilde{\tilde{0}} \; if \; 6\left(\tilde{\tilde{A}}\right) \leq 0 \end{cases} \tag{12}$$

Where, $\tilde{\tilde{0}} = \big((0{,}0{,}0{,}0; 1{,}1), (0{,}0{,}0{,}0; 1{,}1)\big)$.

Definition 6. The ranking value of a trapezoidal IT2FS, denoted as $Rank\ \left(\tilde{\tilde{A}}_i\right)$, is defined by Equation 13.

$$\begin{aligned} Rank\ \left(\tilde{\tilde{A}}_i\right) = {} & M_1\left(\tilde{A}_i^U\right) + M_1\left(\tilde{A}_i^L\right) + M_2\left(\tilde{A}_i^U\right) + M_2\left(\tilde{A}_i^L\right) + M_3\left(\tilde{A}_i^U\right) + M_3\left(\tilde{A}_i^L\right) \\ & - \frac{1}{4}\Big(S_1\left(\tilde{A}_i^U\right) + S_1\left(\tilde{A}_i^L\right) + S_2\left(\tilde{A}_i^U\right) + S_2\left(\tilde{A}_i^L\right) + S_3\left(\tilde{A}_i^U\right) + S_3\left(\tilde{A}_i^L\right) \\ & + S_4\left(\tilde{A}_i^U\right) + S_4\left(\tilde{A}_i^L\right)\Big) + H_1\left(\tilde{A}_i^U\right) + H_1\left(\tilde{A}_i^L\right) + H_2\left(\tilde{A}_i^U\right) + H_2\left(\tilde{A}_i^L\right) \end{aligned} \tag{13}$$

Where, $M_p\left(\tilde{\tilde{A}}_i^j\right)$ represents the average of the values a_{ip}^j and $a_{i(p+1)}^j$.

$$M_p\left(\tilde{\tilde{A}}_i^j\right) = \frac{\left(a_{ip}^j + a_{i(p+1)}^j\right)}{2}, 1 \leq p \leq 3 \tag{14}$$

The standard deviation for the values $a_{i1}^j, a_{i2}^j, a_{i3}^j, a_{i4}^j$ with respect to $S_1\left(\tilde{A}_i^j\right), S_2\left(\tilde{A}_i^j\right)$ and $S_3\left(\tilde{A}_i^j\right)$ is calculated using Equation 15.

$$S_q\left(\tilde{A}_i^j\right) = \sqrt{\frac{1}{2}\sum_{k=q}^{q+1}\left(a_{ik}^j - \frac{1}{2}\sum_{k=q}^{q+1}\left(a_{ik}^j\right)\right)}, 1 \leq p \leq 3 \tag{15}$$

For the values and the standard deviation is calculated as shown in Equation 16, differing from the first three.

$$S_4\left(\tilde{A}_i^j\right) = \sqrt{\frac{1}{4}\sum_{k=4}^{4}\left(a_{ik}^j - \frac{1}{2}\sum_{k=1}^{4}\left(a_{ik}^j\right)\right)^2} \tag{16}$$

3.2. COPRAS Method

The COPRAS method, introduced by Zavadskas and Kaklauskas (1996), is MCDM method that determines a solution based on positive-ideal and negative-ideal solutions, thus being considered as a compromise MCDM method. Originally, the COPRAS method was developed for decision-making under certain conditions. However, uncertainty is an inevitable characteristic of decision-making. In this study, an extended form of the COPRAS method, which can be used in decision-making problems with uncertainty, is proposed using T2FS.

The proposed method in the study is based on applying arithmetic operations among IT2FSs to the steps of the COPRAS method. Let *L* be a set of alternatives, denoted as $L = \{l1, l2, \ldots ln\}$ and be a set of criteria, denoted as $R = \{r1, r2, \ldots rm,\}$. Let's assume that there are decision makers, denoted as $D1, D2, \ldots, Dk$. The steps of the proposed method are listed as follows (Zavadskas et al., 2009).

Step 1: The decision matrix M_p for the th decision maker is formed as shown in Equation 17.

$$M_p = \left[\tilde{\tilde{X}}_{ij}^p\right]_{n\times m} = \begin{bmatrix} \tilde{\tilde{X}}_{11}^p & \tilde{\tilde{X}}_{12}^p & \cdots & \tilde{\tilde{X}}_{1m}^p \\ \tilde{\tilde{X}}_{21}^p & \tilde{\tilde{X}}_{22}^p & \cdots & \tilde{\tilde{X}}_{2m}^p \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{\tilde{X}}_{n1}^p & \tilde{\tilde{X}}_{n2}^p & \cdots & \tilde{\tilde{X}}_{nm}^p \end{bmatrix} \tag{17}$$

Where, $\tilde{\tilde{X}}_{ij}^p$ denotes the performance value of criterion r_j on alternative l_i assigned by the p th decision maker $(1 \leq i \leq n, 1 \leq j \leq m, 1 \leq p \leq k)$.

Step 2: The average decision matrix $\bar{Y}$ is constructed as shown in Equation 19.

$$\tilde{\tilde{\bar{X}}}_{ij} = \left(\left(\tilde{\tilde{X}}_{ij}^1 \oplus \tilde{\tilde{X}}_{ij}^2 \oplus \ldots \oplus \tilde{\tilde{X}}_{ij}^k\right)/k\right) \tag{18}$$

$$\bar{Y} = \left[\tilde{\tilde{\bar{X}}}_{ij}\right]_{n\times m} \tag{19}$$

Where, $\tilde{\tilde{\bar{X}}}_{ij}$ represents the average performance value of criterion r_j on alternative l_i $1 \leq i \leq n, 1 \leq j \leq m, 1 \leq p \leq k)$.

Step 3. The weight matrix is formed by the decision makers using Equation 20.

$$W_p = \left[\tilde{\tilde{w}}_j^p\right]_{m\times 1} = \begin{bmatrix} \tilde{\tilde{w}}_1^p \\ \tilde{\tilde{w}}_2^p \\ \vdots \\ \tilde{\tilde{w}}_m^p \end{bmatrix} \tag{20}$$

Where, $\tilde{\tilde{w}}_j^p$ denotes the weight assigned to criterion r_j by the p th decision maker $(1 \leq i \leq n, 1 \leq j \leq m, 1 \leq p \leq k)$.

Step 4: The average weight matrix $\overline{W}$ is constructed as shown in Equation 22.

$$\tilde{\tilde{w}}_j = \left(\left(\tilde{\tilde{w}}_j^1 \oplus \tilde{\tilde{w}}_j^2 \oplus \ldots \oplus \tilde{\tilde{w}}_j^k\right)/k\right) \tag{21}$$

$$\bar{W} = \left[\tilde{\tilde{w}}_j\right]_{m\times 1} \tag{22}$$

Step 5: The average decision matrix $\bar{Y}$ is normalized, and the normalized *N* matrix is constructed using Equations 23-25.

$$\tilde{\tilde{v}}_j = \left(\tilde{\tilde{X}}_{1j} \oplus \tilde{\tilde{X}}_{2j} \oplus \ldots \oplus \tilde{\tilde{X}}_{nj}\right) \tag{23}$$

$$\tilde{\tilde{n}}_{ij} = \tilde{\tilde{X}}_{ij} \oslash \tilde{\tilde{v}}_j \tag{24}$$

$$N = \left[\tilde{\tilde{n}}_{ij}\right]_{n\times m} \tag{25}$$

Where, $1 \le i \le n\ ve\ 1 \le j \le m.$

Step 6: The weighted normalized decision matrix *E* is determined using Equations 26-27.

$$\tilde{\tilde{e}}_{ij} = \tilde{\tilde{n}}_{ij} \otimes \tilde{\tilde{w}}_j \tag{26}$$

$$E = \left[\tilde{\tilde{e}}_{ij}\right]_{n\times m} \tag{27}$$

Step 7: The sum of weighted normalized values for benefit criteria S_{+i} and non-benefit criteria S_{-i} is calculated using Equations 28-29.

$$\tilde{\tilde{S}}_{+i} = (\tilde{\tilde{e}}_{+i1} \oplus \tilde{\tilde{e}}_{+i2} \oplus \ldots \oplus \tilde{\tilde{e}}_{+im}) \tag{28}$$

$$\tilde{\tilde{S}}_{-i} = (\tilde{\tilde{e}}_{-i1} \oplus \tilde{\tilde{e}}_{-i2} \oplus \ldots \oplus \tilde{\tilde{e}}_{-im}) \tag{29}$$

Where, $\tilde{\tilde{e}}_{+ij}$ and $\tilde{\tilde{e}}_{-ij}$ represent the weighted normalized values for benefit and non-benefit criteria, respectively. The value of $\tilde{\tilde{S}}_{+i}$ indicates how much better the alternative is as it increases, while the value of $\tilde{\tilde{S}}_{-i}$ indicates how much better the alternative is as it decreases. In other words, the values of $\tilde{\tilde{S}}_{+i}$ and $\tilde{\tilde{S}}_{-i}$ define the degree to which the objectives achieved by each alternative.

Step 8: Ranking values are determined for both $\tilde{\tilde{S}}_{+i}$ and $\tilde{\tilde{S}}_{-i}$ $(1 \le i \le n)$ using the equations presented in the IT2FS section.

Step 9: Q_i, which expresses the relative importance of alternatives, is determined using Equation 30.

$$Q_i = \mathrm{Rank}\left(\tilde{\tilde{S}}_{+i}\right) + \frac{\mathrm{Rank}_{\min}\left(\tilde{\tilde{S}}_{-i}\right)\sum_{i=1}^{n}\left(\mathrm{Rank}\left(\tilde{\tilde{S}}_{-i}\right)\right)}{\mathrm{Rank}\left(\tilde{\tilde{S}}_{-i}\right)\sum_{i=1}^{n}\left(\mathrm{Rank}_{\min}\left(\tilde{\tilde{S}}_{-i}\right)\Big/\mathrm{Rank}\left(\tilde{\tilde{S}}_{-i}\right)\right)} \tag{30}$$

Where, $\mathrm{Rank}_{\min}\left(\tilde{\tilde{S}}_{-i}\right)$ represents the minimum value of $\mathrm{Rank}\left(\tilde{\tilde{S}}_{-i}\right)$. The relative importance value defines the degree of satisfaction achieved by an alternative. The formula above can be written as Equation 31.

$$\mathrm{Rank}\left(\tilde{\tilde{S}}_{+i}\right) + \frac{\sum_{i=1}^{n}\left(\mathrm{Rank}\left(\tilde{\tilde{S}}_{-i}\right)\right)}{\mathrm{Rank}\left(\tilde{\tilde{S}}_{-i}\right)\sum_{i=1}^{n}\left(1\Big/\mathrm{Rank}\left(\tilde{\tilde{S}}_{-i}\right)\right)} \tag{31}$$

Step 10: The quantitative aid program U_i is calculated. The degree of benefit of an alternative is determined by comparing the relative importance of all alternatives with the most efficient one, and it is represented as Equation 32.

$$U_i = \left(\frac{Q_i}{Q_{max}}\right) \times 100 \tag{32}$$

In Equation 32, Q_{max} represents the maximum relative significance value. The larger the value of U_i, for $1 \leq i \leq n$, the more preferred the alternative l_i.

4. Analysis and Results

With the advent of Industry 4.0, autonomous technologies widely used in businesses have also started to manifest their impact in agricultural enterprises. As a result of this impact, unmanned aerial vehicles for spraying and fertilization have gained increasing attention in recent years. This technology, becoming important for agricultural enterprises, has led to the production of numerous alternative drones. In the study, criteria used in the selection of agricultural drones were determined, and alternatives were evaluated based on these criteria. The compliance of the study with ethical rules determined by Erzincan Binali Yıldırım Üniversitesi human research social and humanities ethics committee with the dated 23/06/2023 and numbered 06/08.

In this section of the study, the integrated IT2FS-COPRAS method was applied to the drone selection problem. The alternatives under evaluation were determined from drones belonging to two brands commonly used and currently available for sale in Türkiye. All calculations in the study were performed by the author using the Microsoft Excel program.

When determining the criteria used in drone selection, literature and expert opinions were consulted. The nine criteria determined and their explanations are shown in Table 3.

Table 3: Criteria for Drone Selection

Criteria	Target	Code	Description	Author
Price	Min	P	Selling price and operational cost of the product	Nur et al. 2020; Khan et al. 2021; Arslan and Delice 2020
Tank Capacity	Max	TC	Volume of the tank in liters	Rakhade et al. 2021
Operational Efficiency	Max	OE	Area processed per hour in hectares per hour	Expert
Spraying Speed	Max	SS	Volume sprayed per minute in liters	Expert
Safety	Max	S	Ability of the product to avoid obstacles with its sensors and radars	Expert
Communication Features	Max	CF	Maximum transmission distance and connectivity efficiency of the product	Nur et al. 2020; Arslan and Delice 2020; Rakhade et al. 2021
Spraying Abilities	Max	SA	Variety of products sprayed and spraying width based on nozzle characteristics	Rakhade et al. 2021; Expert
Ease of Use	Max	EU	User interface and flight usability of the product	Arslan and Delice 2020; Expert
Take off Weight	Max	TW	Maximum takeoff weight of the product in kilograms	Nur et al. 2020

The price criterion among the determined criteria is cost-oriented, while the other criteria are benefit-oriented. The criteria of wind resistance and efficient flight time, determined through literature review, were excluded from the study based on expert opinion. The necessity for low wind speed in spraying and fertilization renders wind resistance not a sought-after criterion in agricultural drones, as indicated by expert opinion. Additionally, due to the approximate ten-minute efficient flight time for each existing drone, flight time was determined not to be a distinguishing criterion, again based on expert opinion. Moreover, safety, operational efficiency, and spraying speed were added to the study based on expert opinion.

In the study, linguistic terms used by decision-makers to assess the importance of criteria and the performance of alternatives for each criterion, along with their corresponding IT2FS numbers (Chen & Lee, 2010), are shown in Table 4.

Table 4: Interval Type-2 Fuzzy Numbers Corresponding to Linguistic Expressions

Linguistic Expressions	Interval Type-2 Fuzzy Numbers
Very Low (VL)	((0,0,0,0.1;1,1),(0,0,0,0.005;0.9,0.9))
Low (L)	((0,0.1,0.15,0.3;1,1),(0.05,0.1,0.15,0.2;0.9,0.9))
Medium Low (ML)	((0.1,0.3,0.35,0.5;1,1),(0.2,0.3,0.35,0.4;0.9,0.9))
Medium (M)	((0.3,0.5,0.55,0.7;1,1),(0.4,0.5,0.55,0.6;0.9,0.9))
Medium High (MH)	((0.5,0.7,0.75,0.9;1,1),(0.6,0.7,0.75,0.8;0.9,0.9))
High (H)	((0.7,0.85,0.9,1;1,1),(0.8,0.85,0.9,0.95;0.9,0.9))
Very High (VH)	((0.9,1,1,1;1,1),(0.95,1,1,1;0.9,0.9))

In determining the weights of the criteria, opinions were obtained from five experts. The information regarding the experts is shown in Table 5.

Table 5: Information Regarding the Experts

Expert	Abbreviation	Field of Expertise	Experience (Years)
Expert 1	E1	Drone Pilot	4
Expert 2	E2	Drone Pilot	3
Expert 3	E3	Drone Pilot	3
Expert 4	E4	Drone Seller	3
Expert 5	E5	Agricultural Engineer	3

Among the identified experts, there are three drone pilots, a drone sales representative, and an agricultural engineer who uses drones. The experts have a minimum of three years of experience with drones and are currently active in this sector. The opinions of the experts regarding the criteria are presented in Table 5 using linguistic expressions.

Table 6: Linguistic Expressions Corresponding to Criteria Responded by Experts

	P	TC	OE	SS	S	CF	SA	EU	TW
E1	MH	M	ML	M	L	M	M	M	L
E2	L	VH	VH	VH	VH	MH	H	VH	VL
E3	M	VH	VH	VH	VH	VH	VH	VH	M
E4	VL	H	H	H	VH	VH	H	M	H
E5	M	MH	H	H	VH	M	MH	M	VL

The evaluations of the five experts regarding the criterion weights specified in Table 6 were used to create the average criterion matrix using Equations 21-22. The values in the average decision matrix reflect the averages of the values provided by the experts. The average criterion matrix is shown in Table 7.

Table 7: Average Criterion Matrix

Criteria	Interval Type-2 Fuzzy Numbers											
P	0.22	0.36	0.40	0.54	1	1	0.29	0.36	0.40	0.45	0.9	0.9
TC	0.66	0.81	0.84	0.92	1	1	0.74	0.81	0.84	0.87	0.9	0.9
OE	0.66	0.80	0.83	0.90	1	1	0.74	0.80	0.83	0.86	0.9	0.9
SS	0.70	0.84	0.87	0.94	1	1	0.78	0.84	0.87	0.90	0.9	0.9
S	0.72	0.82	0.83	0.86	1	1	0.77	0.82	0.83	0.84	0.9	0.9
CF	0.62	0.78	0.81	0.90	1	1	0.70	0.78	0.81	0.84	0.9	0.9
SA	0.62	0.78	0.82	0.92	1	1	0.71	0.78	0.82	0.86	0.9	0.9
EU	0.54	0.70	0.73	0.82	1	1	0.62	0.70	0.73	0.76	0.9	0.9
TW	0.24	0.39	0.43	0.56	1	1	0.32	0.39	0.43	0.48	0.9	0.9

When Table 7 is examined, the criterion with the highest weight is the spraying rate. This criterion is followed by tank capacity and spraying capability. The criterion with the lowest weight is determined to be price.

In the study, seven alternatives were evaluated by three experts. Only opinions from drone pilots were obtained for the evaluation of alternatives. These drone pilots have tested all of the alternatives. The opinions of the other two experts were not sought because they did not test the flying abilities of the drones. The experts have knowledge and experience with all alternatives. The expert opinions for each alternative are shown in Table 8.

Table 8: Linguistic Expressions Provided by Experts for Each Criterion for Alternatives

Expert	Alternative	P	TC	OE	SS	S	CF	SA	EU	TW
E1	A1	MH	L	ML	ML	H	MH	L	H	L
	A2	MH	H	VH	VH	VH	MH	VH	M	H
	A3	VH	L	ML	ML	VL	VL	ML	ML	L
	A4	H	ML	M	M	VL	VL	ML	ML	ML
	A5	H	M	MH	MH	VL	VL	ML	L	M
	A6	H	MH	H	MH	VL	VL	L	ML	MH
	A7	MH	MH	H	MH	VH	MH	M	M	MH
E2	A1	VL	VL	VL	VL	VL	L	VL	H	L
	A2	M	MH	VH	H	H	VH	VH	VH	VH
	A3	H	VL	VL	L	L	ML	ML	M	L
	A4	H	ML	ML	ML	L	ML	ML	M	ML
	A5	H	ML	M	M	L	ML	ML	M	ML
	A6	H	M	M	M	L	ML	ML	M	ML
	A7	M	M	MH	MH	MH	VH	MH	MH	H
E3	A1	ML	L	M	MH	MH	H	ML	H	L
	A2	VH	VH	VH	VH	VH	VH	VH	M	H
	A3	M	L	ML	M	L	L	ML	MH	L
	A4	MH	ML	M	MH	L	L	M	M	ML
	A5	H	MH	MH	H	L	L	M	M	M
	A6	VH	MH	MH	H	MH	ML	H	M	M
	A7	H	MH	H	VH	VH	VH	H	MH	M

The analysis of experts' opinions on criteria and alternatives using the Interval Type-2 Fuzzy COPRAS method was carried out through the following steps:

Step 1: In the first step of the method, a decision matrix is formed. The decision matrix containing evaluations by decision-makers is created with linguistic expressions in Table 8.

Step 2: The expressions of decision-makers are combined into a single decision by equation 18 to form the average decision matrix. The average decision matrix is presented in Table 9.

Table 9: Integrated Average Decision Matrix

Alternative	**P**	**TC**	**OE**
A1	(0.20 0.33 0.37 0.50 1.00 1.00) (0.27 0.33 0.37 0.42 0.90 0.90)	(0.20 0.33 0.37 0.50 1.00 1.00) (0.27 0.33 0.37 0.42 0.90 0.90)	(0.13 0.27 0.30 0.43 1.00 1.00) (0.20 0.27 0.30 0.35 0.90 0.90)
A2	(0.57 0.73 0.77 0.87 1.00 1.00) (0.65 0.73 0.77 0.80 0.90 0.90)	(0.57 0.73 0.77 0.87 1.00 1.00) (0.65 0.73 0.77 0.80 0.90 0.90)	(0.90 1.00 1.00 1.00 1.00 1.00) (0.95 1.00 1.00 1.00 0.90 0.90)
A3	(0.63 0.78 0.82 0.90 1.00 1.00) (0.72 0.78 0.82 0.85 0.90 0.90)	(0.63 0.78 0.82 0.90 1.00 1.00) (0.72 0.78 0.82 0.85 0.90 0.90)	(0.07 0.20 0.23 0.37 1.00 1.00) (0.13 0.20 0.23 0.28 0.90 0.90)
A4	(0.63 0.80 0.85 0.97 1.00 1.00) (0.73 0.80 0.85 0.90 0.90 0.90)	(0.63 0.80 0.85 0.97 1.00 1.00) (0.73 0.80 0.85 0.90 0.90 0.90)	(0.23 0.43 0.48 0.63 1.00 1.00) (0.33 0.43 0.48 0.53 0.90 0.90)
A5	(0.70 0.85 0.90 1.00 1.00 1.00) (0.80 0.85 0.90 0.95 0.90 0.90)	(0.70 0.85 0.90 1.00 1.00 1.00) (0.80 0.85 0.90 0.95 0.90 0.90)	(0.43 0.63 0.68 0.83 1.00 1.00) (0.53 0.63 0.68 0.73 0.90 0.90)
A6	(0.77 0.90 0.93 1.00 1.00 1.00) (0.85 0.90 0.93 0.97 0.90 0.90)	(0.77 0.90 0.93 1.00 1.00 1.00) (0.85 0.90 0.93 0.97 0.90 0.90)	(0.50 0.68 0.73 0.87 1.00 1.00) (0.60 0.68 0.73 0.78 0.90 0.90)
A7	(0.50 0.68 0.73 0.87 1.00 1.00) (0.60 0.68 0.73 0.78 0.90 0.90)	(0.50 0.68 0.73 0.87 1.00 1.00) (0.60 0.68 0.73 0.78 0.90 0.90)	(0.63 0.80 0.85 0.97 1.00 1.00) (0.73 0.80 0.85 0.90 0.90 0.90)
Alternative	**SS**	**S**	**CF**
A1	(0.20 0.33 0.37 0.50 1.00 1.00) (0.27 0.33 0.37 0.42 0.90 0.90)	(0.40 0.52 0.55 0.67 1.00 1.00) (0.47 0.52 0.55 0.60 0.90 0.90)	(0.40 0.55 0.60 0.73 1.00 1.00) (0.48 0.55 0.60 0.65 0.90 0.90)
A2	(0.83 0.95 0.97 1.00 1.00 1.00) (0.90 0.95 0.97 0.98 0.90 0.90)	(0.83 0.95 0.97 1.00 1.00 1.00) (0.90 0.95 0.97 0.98 0.90 0.90)	(0.77 0.90 0.92 0.97 1.00 1.00) (0.83 0.90 0.92 0.93 0.90 0.90)
A3	(0.13 0.30 0.35 0.50 1.00 1.00) (0.22 0.30 0.35 0.40 0.90 0.90)	(0.00 0.07 0.10 0.23 1.00 1.00) (0.03 0.07 0.10 0.15 0.90 0.90)	(0.03 0.13 0.17 0.30 1.00 1.00) (0.08 0.13 0.17 0.22 0.90 0.90)
A4	(0.30 0.50 0.55 0.70 1.00 1.00) (0.40 0.50 0.55 0.60 0.90 0.90)	(0.00 0.07 0.10 0.23 1.00 1.00) (0.03 0.07 0.10 0.15 0.90 0.90)	(0.03 0.13 0.17 0.30 1.00 1.00) (0.08 0.13 0.17 0.22 0.90 0.90)
A5	(0.50 0.68 0.73 0.87 1.00 1.00) (0.60 0.68 0.73 0.78 0.90 0.90)	(0.00 0.07 0.10 0.23 1.00 1.00) (0.03 0.07 0.10 0.15 0.90 0.90)	(0.03 0.13 0.17 0.30 1.00 1.00) (0.08 0.13 0.17 0.22 0.90 0.90)
A6	(0.50 0.68 0.73 0.87 1.00 1.00) (0.60 0.68 0.73 0.78 0.90 0.90)	(0.17 0.27 0.30 0.43 1.00 1.00) (0.22 0.27 0.30 0.35 0.90 0.90)	(0.07 0.20 0.23 0.37 1.00 1.00) (0.13 0.20 0.23 0.28 0.90 0.90)
A7	(0.63 0.80 0.83 0.93 1.00 1.00) (0.72 0.80 0.83 0.87 0.90 0.90)	(0.77 0.90 0.92 1.00 1.00 1.00) (0.83 0.90 0.92 0.93 0.90 0.90)	(0.77 0.90 0.92 0.97 1.00 1.00) (0.83 0.90 0.92 0.93 0.90 0.90)
Alternative	**SA**	**EU**	**TW**
A1	(0.03 0.13 0.17 0.30 1.00 1.00) (0.08 0.13 0.17 0.22 0.90 0.90)	(0.70 0.85 0.90 1.00 1.00 1.00) (0.80 0.85 0.90 0.95 0.90 0.90)	(0.00 0.10 0.15 0.30 1.00 1.00) (0.05 0.10 0.15 0.20 0.90 0.90)
A2	(0.90 1.00 1.00 1.00 1.00 1.00) (0.95 1.00 1.00 1.00 0.90 0.90)	(0.50 0.67 0.70 0.80 1.00 1.00) (0.58 0.67 0.70 0.73 0.90 0.90)	(0.77 0.90 0.93 1.00 1.00 1.00) (0.85 0.90 0.93 0.97 0.90 0.90)
A3	(0.10 0.30 0.35 0.50 1.00 1.00) (0.20 0.30 0.35 0.40 0.90 0.90)	(0.30 0.50 0.55 0.70 1.00 1.00) (0.40 0.50 0.55 0.60 0.90 0.90)	(0.00 0.10 0.15 0.30 1.00 1.00) (0.05 0.10 0.15 0.20 0.90 0.90)
A4	(0.17 0.37 0.42 0.57 1.00 1.00) (0.27 0.37 0.42 0.47 0.90 0.90)	(0.23 0.43 0.48 0.63 1.00 1.00) (0.33 0.43 0.48 0.53 0.90 0.90)	(0.10 0.30 0.35 0.50 1.00 1.00) (0.20 0.30 0.35 0.40 0.90 0.90)
A5	(0.17 0.37 0.42 0.57 1.00 1.00) (0.27 0.37 0.42 0.47 0.90 0.90)	(0.20 0.37 0.42 0.57 1.00 1.00) (0.28 0.37 0.42 0.47 0.90 0.90)	(0.23 0.43 0.48 0.63 1.00 1.00) (0.33 0.43 0.48 0.53 0.90 0.90)
A6	(0.27 0.42 0.47 0.60 1.00 1.00) (0.35 0.42 0.47 0.52 0.90 0.90)	(0.23 0.43 0.48 0.63 1.00 1.00) (0.33 0.43 0.48 0.53 0.90 0.90)	(0.30 0.50 0.55 0.70 1.00 1.00) (0.40 0.50 0.55 0.60 0.90 0.90)
A7	(0.63 0.80 0.83 0.93 1.00 1.00) (0.60 0.68 0.73 0.78 0.90 0.90)	(0.43 0.63 0.68 0.83 1.00 1.00) (0.53 0.63 0.68 0.73 0.90 0.90)	(0.50 0.68 0.73 0.87 1.00 1.00) (0.60 0.68 0.73 0.78 0.90 0.90)

Step 3: The decision matrix for each decision-maker's evaluation of the criteria is constructed with linguistic expressions in Table 4.

Step 4: The average criterion matrix is formed from the criterion decision matrix using Equations 21-22. This matrix is presented in Table 7.

Steps 5-6: In these steps, the average decision matrix is normalized using Equations 23-24. Then, the normalized matrix is weighted using Equation 24. The values of the weighted normalized matrix are provided in Table 10.

Table 10: Weighted Normalized Matrix

Cr	Alternative	Weighted Interval Type-2 Fuzzy Number											
P	A1	0.011	0.024	0.027	0.044	1	1	0.017	0.024	0.027	0.033	0.9	0.9
	A2	0.031	0.052	0.057	0.077	1	1	0.041	0.052	0.057	0.064	0.9	0.9
	A3	0.035	0.055	0.061	0.08	1	1	0.045	0.055	0.061	0.068	0.9	0.9
	A4	0.035	0.057	0.063	0.086	1	1	0.046	0.057	0.063	0.071	0.9	0.9
	A5	0.039	0.06	0.067	0.089	1	1	0.05	0.06	0.067	0.075	0.9	0.9
	A6	0.042	0.064	0.07	0.089	1	1	0.053	0.064	0.07	0.077	0.9	0.9
	A7	0.028	0.048	0.055	0.077	1	1	0.038	0.048	0.055	0.062	0.9	0.9
TC	A1	0.011	0.024	0.027	0.044	1	1	0.017	0.024	0.027	0.033	0.9	0.9
	A2	0.031	0.052	0.057	0.077	1	1	0.041	0.052	0.057	0.064	0.9	0.9
	A3	0.035	0.055	0.061	0.08	1	1	0.045	0.055	0.061	0.068	0.9	0.9
	A4	0.035	0.057	0.063	0.086	1	1	0.046	0.057	0.063	0.071	0.9	0.9
	A5	0.039	0.06	0.067	0.089	1	1	0.05	0.06	0.067	0.075	0.9	0.9
	A6	0.042	0.064	0.07	0.089	1	1	0.053	0.064	0.07	0.077	0.9	0.9
	A7	0.028	0.048	0.055	0.077	1	1	0.038	0.048	0.055	0.062	0.9	0.9
OE	A1	0.011	0.024	0.027	0.044	1	1	0.017	0.024	0.027	0.033	0.9	0.9
	A2	0.031	0.052	0.057	0.077	1	1	0.041	0.052	0.057	0.064	0.9	0.9
	A3	0.035	0.055	0.061	0.08	1	1	0.045	0.055	0.061	0.068	0.9	0.9
	A4	0.035	0.057	0.063	0.086	1	1	0.046	0.057	0.063	0.071	0.9	0.9
	A5	0.039	0.06	0.067	0.089	1	1	0.05	0.06	0.067	0.075	0.9	0.9
	A6	0.042	0.064	0.07	0.089	1	1	0.053	0.064	0.07	0.077	0.9	0.9
	A7	0.028	0.048	0.055	0.077	1	1	0.038	0.048	0.055	0.062	0.9	0.9
SS	A1	0.011	0.024	0.027	0.044	1	1	0.017	0.024	0.027	0.033	0.9	0.9
	A2	0.031	0.052	0.057	0.077	1	1	0.041	0.052	0.057	0.064	0.9	0.9
	A3	0.035	0.055	0.061	0.08	1	1	0.045	0.055	0.061	0.068	0.9	0.9
	A4	0.035	0.057	0.063	0.086	1	1	0.046	0.057	0.063	0.071	0.9	0.9
	A5	0.039	0.06	0.067	0.089	1	1	0.05	0.06	0.067	0.075	0.9	0.9
	A6	0.042	0.064	0.07	0.089	1	1	0.053	0.064	0.07	0.077	0.9	0.9
	A7	0.028	0.048	0.055	0.077	1	1	0.038	0.048	0.055	0.062	0.9	0.9

Cr	Alternative	Weighted Interval Type-2 Fuzzy Number											
S	A1	0.011	0.024	0.027	0.044	1	1	0.017	0.024	0.027	0.033	0.9	0.9
	A2	0.031	0.052	0.057	0.077	1	1	0.041	0.052	0.057	0.064	0.9	0.9
	A3	0.035	0.055	0.061	0.08	1	1	0.045	0.055	0.061	0.068	0.9	0.9
	A4	0.035	0.057	0.063	0.086	1	1	0.046	0.057	0.063	0.071	0.9	0.9
	A5	0.039	0.06	0.067	0.089	1	1	0.05	0.06	0.067	0.075	0.9	0.9
	A6	0.042	0.064	0.07	0.089	1	1	0.053	0.064	0.07	0.077	0.9	0.9
	A7	0.028	0.048	0.055	0.077	1	1	0.038	0.048	0.055	0.062	0.9	0.9
CF	A1	0.011	0.024	0.027	0.044	1	1	0.017	0.024	0.027	0.033	0.9	0.9
	A2	0.031	0.052	0.057	0.077	1	1	0.041	0.052	0.057	0.064	0.9	0.9
	A3	0.035	0.055	0.061	0.08	1	1	0.045	0.055	0.061	0.068	0.9	0.9
	A4	0.035	0.057	0.063	0.086	1	1	0.046	0.057	0.063	0.071	0.9	0.9
	A5	0.039	0.06	0.067	0.089	1	1	0.05	0.06	0.067	0.075	0.9	0.9
	A6	0.042	0.064	0.07	0.089	1	1	0.053	0.064	0.07	0.077	0.9	0.9
	A7	0.028	0.048	0.055	0.077	1	1	0.038	0.048	0.055	0.062	0.9	0.9
SA	A1	0.011	0.024	0.027	0.044	1	1	0.017	0.024	0.027	0.033	0.9	0.9
	A2	0.031	0.052	0.057	0.077	1	1	0.041	0.052	0.057	0.064	0.9	0.9
	A3	0.035	0.055	0.061	0.08	1	1	0.045	0.055	0.061	0.068	0.9	0.9
	A4	0.035	0.057	0.063	0.086	1	1	0.046	0.057	0.063	0.071	0.9	0.9
	A5	0.039	0.06	0.067	0.089	1	1	0.05	0.06	0.067	0.075	0.9	0.9
	A6	0.042	0.064	0.07	0.089	1	1	0.053	0.064	0.07	0.077	0.9	0.9
	A7	0.028	0.048	0.055	0.077	1	1	0.038	0.048	0.055	0.062	0.9	0.9
EU	A1	0.011	0.024	0.027	0.044	1	1	0.017	0.024	0.027	0.033	0.9	0.9
	A2	0.031	0.052	0.057	0.077	1	1	0.041	0.052	0.057	0.064	0.9	0.9
	A3	0.035	0.055	0.061	0.08	1	1	0.045	0.055	0.061	0.068	0.9	0.9
	A4	0.035	0.057	0.063	0.086	1	1	0.046	0.057	0.063	0.071	0.9	0.9
	A5	0.039	0.06	0.067	0.089	1	1	0.05	0.06	0.067	0.075	0.9	0.9
	A6	0.042	0.064	0.07	0.089	1	1	0.053	0.064	0.07	0.077	0.9	0.9
	A7	0.028	0.048	0.055	0.077	1	1	0.038	0.048	0.055	0.062	0.9	0.9
TW	A1	0.011	0.024	0.027	0.044	1	1	0.017	0.024	0.027	0.033	0.9	0.9
	A2	0.031	0.052	0.057	0.077	1	1	0.041	0.052	0.057	0.064	0.9	0.9
	A3	0.035	0.055	0.061	0.08	1	1	0.045	0.055	0.061	0.068	0.9	0.9
	A4	0.035	0.057	0.063	0.086	1	1	0.046	0.057	0.063	0.071	0.9	0.9
	A5	0.039	0.06	0.067	0.089	1	1	0.05	0.06	0.067	0.075	0.9	0.9
	A6	0.042	0.064	0.07	0.089	1	1	0.053	0.064	0.07	0.077	0.9	0.9
	A7	0.028	0.048	0.055	0.077	1	1	0.038	0.048	0.055	0.062	0.9	0.9

**Cr:Criteria*

Step 7: $\left(\tilde{\tilde{S}}_{+i}\right)$ and $\text{ank}\left(\tilde{\tilde{S}}_{-i}\right)$ values for each criterion for the alternatives are obtained using Equations 28-29. These values are shown in Table 11.

Table 11: Rank Values for Alternatives

	Non Benefit	Benefit							
Alternative	**P**	**TC**	**OE**	**SS**	**S**	**CF**	**SA**	**EU**	**TW**
A1	0.023	0.019	0.05	0.063	0.142	0.139	0.031	0.149	0.014
A2	0.049	0.219	0.191	0.181	0.258	0.224	0.233	0.113	0.111
A3	0.053	0.019	0.037	0.055	0.02	0.034	0.064	0.084	0.014
A4	0.055	0.07	0.08	0.092	0.02	0.034	0.08	0.072	0.035
A5	0.058	0.123	0.119	0.129	0.02	0.034	0.08	0.062	0.052
A6	0.061	0.159	0.13	0.129	0.073	0.048	0.097	0.072	0.06
A7	0.047	0.159	0.154	0.151	0.243	0.224	0.158	0.107	0.084

Steps 8-10: Q_i and U_i values are calculated using Equations 30-32. Based on these values, the alternatives are ranked. The values related to the ranking of alternatives are shown in Table 12.

Table 12: Ranking Values for Alternatives

Alternative	$\tilde{\tilde{S}}_{+i}$	$\tilde{\tilde{S}}_{-i}$	$\tilde{\tilde{S}}_{min}/\tilde{\tilde{S}}_{-i}$	Q_i	U_i	**Sıralama**
A1	0.606	0.023	1	0.609	39.76	5
A2	1.531	0.049	0.472	1.533	100	1
A3	0.327	0.053	0.44	0.333	21.76	7
A4	0.483	0.055	0.424	0.487	31.8	6
A5	0.62	0.058	0.398	0.624	40.69	4
A6	0.768	0.061	0.381	0.771	50.32	3
A7	1.281	0.047	0.498	1.283	83.69	2

When Table 12 is examined, it can be seen that A2 is the best alternative. The other alternatives are ranked as follows: A7, A6, A5, A1, A4 and A3.

5. Sensitivity Analysis

In the study, a two-step sensitivity analysis was conducted to validate the results of the proposed method. In the first step, analysis was repeated with six different MCDM methods based on IT2FS. Ease of use, simplicity, applicability to real problems, and the use of different calculation algorithms have been influential in determining these methods (Ecer, 2021:10). The ranking results obtained were then determined again using the Borda technique. This technique consolidates multiple MCDM results into a single outcome, thereby generating an overall ranking from the results obtained with different MCDM methods. The results obtained with other MCDM methods and the Borda technique are shown in Figure 2.

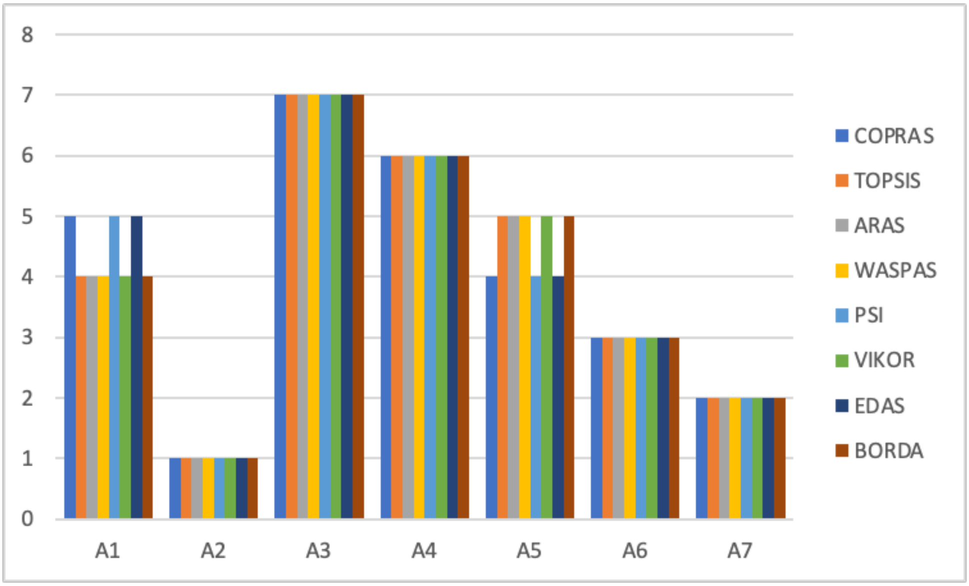


Figure 2: Results of the MCDM Methods and Borda Technique

When examining Figure 2, it is observed that alternatives A2, A3, A4, A6, and A7 received the same ranking value in all methods. To compare the findings obtained from other MCDM methods and the Borda technique, the Spearman correlation coefficient was used. The Spearman correlation coefficient investigates the consistency between results obtained from different methods. For there to be a significant statistical correlation between the results, the Spearman correlation value is expected to be greater than 0.6 (Ghorabaee et al., 2016). The results of the Spearman correlation test are shown in Table 13.

Table 13: Results of the Spearman Correlation Test

	TOPSIS	ARAS	WASPAS	PSI	VIKOR	EDAS	BORDA
COPRAS	0,964**	0,964**	0,964**	1,000**	0,964**	1,000**	0,964**

***Significant at the 0.01 level*

Table 13 shows the results of the comparison between the proposed method and other methods. According to this table, all correlation coefficients are greater than 0.6. This indicates a strong relationship between the ranking results of the extended COPRAS method and other methods. Therefore, it can be stated that the results of the proposed method are consistent with the results of other methods.

In the second step of the sensitivity analysis, analysis was conducted by assigning different values to the criteria. In the analysis, four different linguistic variables (VL, LM, MH, and VH) were assigned to a criterion from low to high, while the other criteria were kept constant. This analysis was performed for nine criteria, and the rankings of alternatives were recorded. The results obtained for each criterion are shown in Appendix 1.

Upon examining Appendix 1, it is observed that in the analyses conducted by changing the criteria weights, A2 is consistently identified as the best alternative in all trials. Similarly, in all trials, alternative A7 is ranked second, A6 is ranked third, A4 is ranked sixth, and A3 is ranked seventh. While alternative A5 mostly ranks fourth, alternative A1 mostly ranks fifth. Therefore, the ranking of alternatives is A2>A7>A6>A1>A5>A4>A3. This ranking result is consistent with the findings of the proposed method. Hence, it can be concluded that the results of the study are stable.

Based on the findings obtained in both steps of sensitivity analysis, it is evaluated that the analysis results are consistent and stable.

6. Discussion and Conclusion

Industry 4.0 and digitalization have brought significant changes to business operations. Advancements in communication, battery, and artificial intelligence have facilitated the progress of drone technology, thus enabling its use in various fields. Drones, which have created their own market in agriculture, are used for weed detection, land mapping, spraying, and fertilization. Agricultural drones customized for use in spraying and fertilization determine the most suitable distribution route according to the terrain structure and autonomously complete the operations. With their aerial mobility, drones are particularly advantageous in rugged terrain compared to other agricultural tools. As stated, the use of agricultural drones, which have significant advantages, has been increasing in recent years. There are various criteria depending on different expectations in the selection of agricultural drones. Since the evaluation of alternatives considering criteria, the decision problem can be solved using MCDM methods. Fuzzy MCDM methods have been used to determine the most suitable agricultural drone among alternatives.

Due to the possibility of personal judgments causing uncertainty in drone selection, fuzzy numbers have been included in the analysis. Therefore, the most suitable agricultural drone among alternatives has been determined using fuzzy MCDM methods.

Since the judgments of users are involved in the process of drone selection, expert opinions have been consulted. Three drone pilots who have experienced all the selected alternatives were asked to evaluate the alternatives. In determining the weights of criteria, the opinions of drone pilots, as well as an agricultural engineer and a representative of a company selling agricultural drones, were obtained. Thus, the evaluation of agricultural drones has been made not only in terms of their field use impact but also in terms of agricultural and operational costs. The data obtained were analyzed using the IT2FS-based COPRAS method. The results obtained indicate that the safety criterion has the highest importance. Among the alternatives, A2 has been identified as the most suitable model. This model is followed by A7, A6, A5, A1, A4, and A3, respectively.

It is believed that the study will contribute to the literature in various aspects. Although studies on drone selection using MCDM methods exist in the literature, it can be stated that there are gaps in terms of research. While some studies use real values (Rakhade et al., 2021; Khan et al., 2021), there are also studies using fuzzy numbers (Nur et al., 2021). A different study evaluating agricultural drones with expert opinion could not be found. The criteria of safety, operational efficiency, and spraying speed have been used for the first time based on expert opinion. In addition, the use of IT2FS in drone selection adds original value to the study. Furthermore, it is thought that the study will contribute to the literature on product and supplier selection using IT2FS-based MCDM methods.

Although the study has valuable contributions, there are also some limitations. Only seven alternatives belonging to two drone brands commonly available and widely used in Türkiye were included in the study. Since the results of the study are based on expert opinion, they may be influenced by personal judgments. Although there are numerous criteria for evaluating drones in the literature, only nine criteria based on expert opinion were used in the study.

In future studies addressing drone selection problems, integrated methods where criteria weights are calculated separately can be used. Analyses can be conducted based on unstable, global, neutrosophic, or intuitive fuzzy numbers instead of IT2FS numbers. In the study, a subjective result based on expert opinion was obtained. Objective results can be obtained by weighting using methods such as CRITIC, ENTROPY, MEREC, and SD. Finally, the content of the study can be expanded by increasing the number of criteria and alternatives.

Financial Support

The authors have not received any financial support for this study.

References

Ahirwar, S., Swarnkar, R., Bhukya, S. & Namwade, G. (2019). Application of drone in agriculture. *International Journal of Current Microbiology and Applied Sciences, 8*(01), 2500-2505.

Aka, D. Ç. (2022). Endüstri 4.0'ın uygulanmasında kritik başarı faktörlerinin belirlenmesi ve aralık tip-2 bulanık TOPSIS Yöntemi ile yatırım teşviği alan firmaların durum değerlendirilmesi. *Avrupa Bilim ve Teknoloji Dergisi, 41*, 36-47.

Aksoy, E., Ömürbek, N. & Karaatlı, M. (2015). AHP temelli MULTIMOORA ve COPRAS yöntemi ile Türkiye Kömür İşletmeleri'nin performans değerlendirmesi. *Hacettepe Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi, 33*(4), 1-28.

Alkan, B. & Ertuğrul, G. Ö. (2022). Tarımsal insansız hava araçları ile pestisit uygulamaları. *Kırşehir Ahi Evran Üniversitesi Ziraat Fakültesi Dergisi, 2*(2), 232-238.

Arslan, N. & Delice, E. K. (2020). KEMIRA-M yöntemi ile kişisel kullanıcılar için dron seçimi: bir uygulama. *Endüstri Mühendisliği, 31*(2), 159-179.

Celik, E., Yucesan, M. & Gul, M. (2021). Green supplier selection for textile industry: a case study using BWM-TODIM integration under interval type-2 fuzzy sets. *Environmental Science and Pollution Research, 28*, 64793-64817.

Chen, S. M. & Lee, L. W. (2010). Fuzzy multiple attributes group decision-making based on the interval type-2 TOPSIS method. *Expert Systems with Applications, 37*(4), 2790-2798.

Çalık, A. (2019). Yüklenici değerlendirme sürecinde aralıklı tip2 bulanık TOPSİS yöntemi uygulaması: küçük ve orta ölçekli işletmelerde KOBİ'ler bir örnek olay çalışması. *Iğdır Üniversitesi Sosyal Bilimler Dergisi, 18*, 481-501.

Dorfeshan, Y., Mousavi, S. M., Zavadskas, E. K. & Antucheviciene, J. (2021). A new enhanced ARAS method for critical path selection of engineering projects with interval type-2 fuzzy sets. *International Journal of Information Technology & Decision Making, 20*(01), 37-65.

Dutta, G. & Goswami, P. (2020). Application of drone in agriculture: A review. *International Journal of Chemical Studies, 8*(5), 181-187.

Ecer, F. (2021). A consolidated MCDM framework for performance assessment of battery electric vehicles based on ranking strategies. *Renewable and Sustainable Energy Reviews, 143*, 110916.

Ecer, F. (2022). Multi-criteria decision making for green supplier selection using interval type-2 fuzzy AHP: a case study of a home appliance manufacturer. *Operational Research, 22*(1), 199-233.

Ercan, Ş., Öztep, R., Güler, D. & Saner, G. (2019). Tarım 4.0 ve Türkiye'de uygulanabilirliğinin değerlendirilmesi. *Tarım Ekonomisi Dergisi, 25*(2), 259-265.

Ghorabaee, M. K. (2016). Developing an MCDM method for robot selection with interval type-2 fuzzy sets. *Robotics and Computer-Integrated Manufacturing, 37*, 221-232.

Ghorabaee, M. K., Amiri, M., ., Sadaghiani, J. S. & Goodarzi, H. G. (2014). Multiple criteria group decision-making for supplier selection based on COPRAS method with interval type-2 fuzzy sets. *The İnternational Journal of Advanced Manufacturing Technology, 75*, 1115-1130.

Ghorabaee, M. K., Amiri, M., Sadaghiani, J. S. & Zavadskas, E. K. (2015). Multi-criteria project selection using an extended VIKOR method with interval type-2 fuzzy sets. *International Journal of Information Technology & Decision Making, 14*(05), 993-1016.

Ghorabaee, M. K., Amiri, M., Zavadskas, E. K & Antucheviciene, J. (2017). Supplier evaluation and selection in fuzzy environments: a review of MADM approaches. *Economic Research-Ekonomska İstraživanja, 30*(1), 1073-1118.

Ghorabaee, M. K., Amiri, M., Zavadskas, E. K., Turskis, Z. & Antucheviciene, J. (2017). A new multi-criteria model based on interval type-2 fuzzy sets and EDAS method for supplier evaluation and order allocation with environmental considerations. *Computers & Industrial Engineering, 112*, 156-174.

Ho, W., Xu, X. & Dey, P. K. (2010). Multi-criteria decision making approaches for supplier evaluation and selection: A literature review, *European Journal of Operational Research, 202*(1), 16-24.

Hoseini, S. A., Zolfani, H. S., Skačkauskas, P., Fallahpour, A. & Saberi, S. (2021). A combined interval type-2 fuzzy MCDM framework for the resilient supplier selection problem. *Mathematics, 10*(1), 44.

Ighravwe, D. & Babatunde, M. (2018). Selection of a mini-grid business model for developing countries using CRITIC-TOPSIS with interval type-2 fuzzy sets. *Decision Science Letters, 7*(4), 427-442.

İnan, M. & Karcı, A. (2021). Tarımda ağaç ilaçlamanın drone'larla yapılmasında yeni bir yöntemin geliştirilmesi ve uygulanması. *Computer Science, 6*(2), 72-89.

John, R. & Coupland, S. (2007). Type-2 fuzzy logic: a historical view. *IEEE Computational Intelligence Magazine, 2*(1), 57-62.

Karagöz, S., Deveci, M., Simic, V. & Aydin, N. (2021). Interval type-2 fuzzy ARAS method for recycling facility location problems. *Applied Soft Computing, 102*, 107107.

Kaya, S. K. & Aycin, E. (2021). An integrated interval type 2 fuzzy AHP and COPRAS-G methodologies for supplier selection in the era of Industry 4.0. *Neural Computing and Applications, 33*(16), 10515-10535.

Khan, M. S., Shah, S. I. A., Javed, A., Qadri, N. M. & Hussain, N. (2021). Drone selection using multi-criteria decision-making methods. In 2021 International Bhurban Conference on Applied Sciences and Technologies (IBCAST), January, 256-270.

Kılavuz, E. & Erdem, İ. (2019). Dünyada tarım 4.0 uygulamaları ve Türk tarımının dönüşümü. *Social Sciences, 14*(4), 133-157.

Mardani, A., Jusoh, A., Zavadskas, E. K., Khalifah, Z. & Nor, K. M. (2015). Application of multiple-criteria decision-making techniques and approaches to evaluating of service quality: a systematic review of the literature. *Journal of Business Economics and Management, 16*(5), 1034-1068.

Mendel, J. M., John, R. I. & Liu, F. (2006). Interval type-2 fuzzy logic systems made simple. *IEEE Transactions on Fuzzy Systems, 14*(6), 808-821.

Mogili, U. R. & Deepak, B. B. V. L. (2018). Review on application of drone systems in precision agriculture. *Procedia computer science, 133*, 502-509.

Mohamadghasemi, A., Hadi-Vencheh, A., Lotfi, F. H., & Khalilzadeh, M. (2020). An integrated group FWA-ELECTRE III approach based on interval type-2 fuzzy sets for solving the MCDM problems using limit distance mean. *Complex & Intelligent Systems, 6*, 355-389.

Mohamadghasemi, A., Vencheh, A. H., Lotfi, F. H. & Khalilzadeh, M. (2020). An integrated group FWA-ELECTRE III approach based on interval type-2 fuzzy sets for solving the MCDM problems using limit distance mean. *Complex & Intelligent Systems, 6*, 355-389.

Mohammadi, H., Farahani, F. V., Noroozi, M., & Lashgari, A. (2017). Green supplier selection by developing a new group decision-making method under type 2 fuzzy uncertainty. *The International Journal of Advanced Manufacturing Technology, 93*, 1443-1462.

Ntalakas, A., Dimoulas, C., Kalliris, G., & Veglis, A. (2017). Drone journalism: Generating immersive experiences. *Journal of Media Critiques, 3*(11), 187-199.

Nur, F., Alrahahleh, A., Burch, R., Babski-Reeves, K. & Marufuzzaman, M. (2020). Last mile delivery drone selection and evaluation using the interval-valued inferential fuzzy TOPSIS. *Journal of Computational Design and Engineering, 7*(4), 397-411.

Oztaysi, B. (2015). A group decision making approach using interval type-2 fuzzy AHP for enterprise information systems project selection. *Journal of Multiple-Valued Logic & Soft Computing, 24*, 475-500.

Özgüven, M. M., Altaş, Z., Güven, D. & Arif, Ç. A. M. (2022). Tarımda drone kullanımı ve geleceği. Ordu Üniversitesi Bilim ve Teknoloji Dergisi, 12(1), 64-83.

Özyurt, H. B., Duran, H. & Çelen, I. H. (2022). Determination of the application parameters of spraying drones for crop production in hazelnut orchards. *Tekirdağ Ziraat Fakültesi Dergisi, 19*(4), 819-828.

Paksoy, T. & Öztürk, M. (2019). Aralık Tip-2 bulanık kural tabanlı AHP yaklaşımı ile tedarikçi seçimi. *Verimlilik Dergisi, 3,* 115-141.

Puri, V., Nayyar, A. & Raja, L. (2017). Agriculture drones: A modern breakthrough in precision agriculture. *Journal of Statistics and Management Systems, 20*(4), 507-518.

Rakhade, R. D., Patil, N. V., Pardeshi, M. R. & Mhasde, C. S. (2021). Optimal choice of agricultural drone using MADM methods. International Journal of Technological Innovation in Modern Engineering and Science (IJTIMES), e-ISSN, 2455, 2585.

Sen, B., Hussain, S. A. I., Gupta, A. D., Gupta, M. K., Pimenov, D. Y. & Mikołajczyk, T. (2020). Application of type-2 fuzzy AHP-ARAS for selecting optimal WEDM parameters. Metals 2021, 11, 42.

Triantaphyllou E. (2010), Multi-Criteria Decision Making Methods: A Comparative Study, Springer.

Türkiye Bankalar Birliği (TBB), 2023. https://www.tbb.org.tr/Content/Upload/Dokuman/8960/Tarim_Sektor_Raporu_130723.pdf

Vatansever, K. & Tellioğlu, S. (2020). Aralık Tip-II Bulanık TOPSIS yöntemi ile bir konaklama işletmesinde tedarikçi seçimi. *Ankara Hacı Bayram Veli Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi, Özel Sayı*, 133-155.

Yangal, H. S., Karakoç, A., Akbulut, A. & Gedikağaoğlu, M. (2022). Kil topu ile uygulamalı drone destekli akıllı tohumlama ve ağaçlandırma. *Uluslararası Biyosistem Mühendisliği Dergisi, 3*(1), 18-31.

Yıldız, A., Ayyıldız, E., Gümüş, A. T. & Özkan, C. (2022). Şehirlerarası otobüs firmalarına yönelik kalite beklentilerinin aralıklı tip-2 yamuk bulanık AHP ile değerlendirilmesi ve firma seçimi. *Gazi Üniversitesi Mühendislik Mimarlık Fakültesi Dergisi, 37*(2), 757-770.

Zadeh, L. A. (1975). Fuzzy logic and approximate reasoning: In memory of grigore moisil. *Synthese, 30*, 407-428.

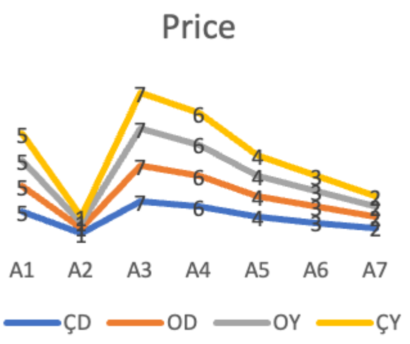
Zavadskas, E. K. & Kaklauskas, A. (1996). Multicriteria Evaluation of Building (Pastatų sistemotechninis įvertinimas). Vilnius: Technika

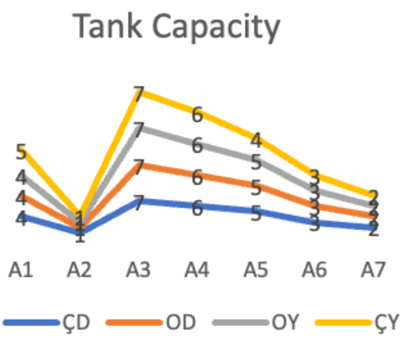
Zavadskas, E. K., Kaklauskas, A., Turskis, Z. & Tamošaitienė, J. (2009). Multi-attribute decision-making model by applying grey numbers. *Informatica, 20*(2), 305-320.

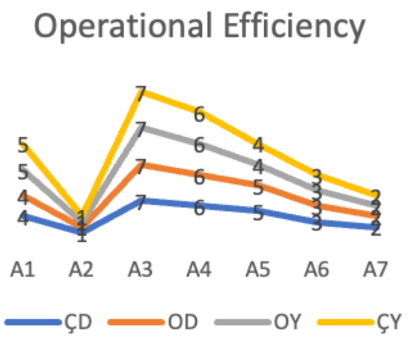
Resume

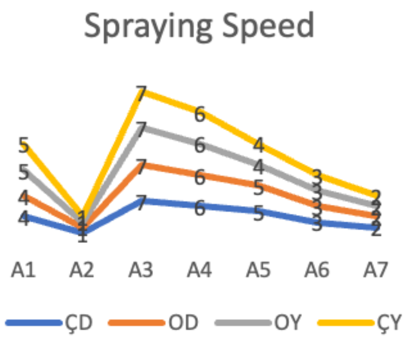
Alparslan OĞUZ (Assist. Prof. Dr.), is Assistant Professor at the Department of Office Services and Secretarial, Erzincan Binali Yıldırım University. He holds a Ph.D. in business administration from Karadeniz Technical University. His research interests focus on the areas supply chain management and multi-criteria decision-making methods. His research has appeared in the International Journal of Economics and Administrative Studies, the Hacettepe University Journal of Economics and Administrative Sciences, the Anadolu University Journal of the Faculty of Economics and Administrative Sciences and the Business and Economics Research Journal.

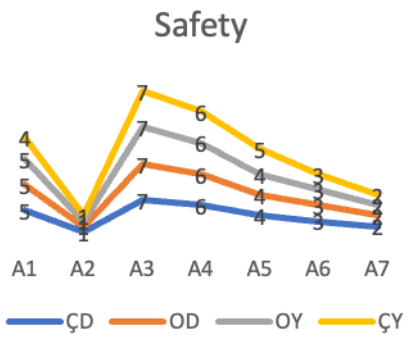
Appendix 1

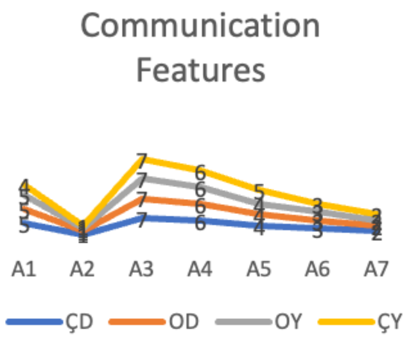

Price

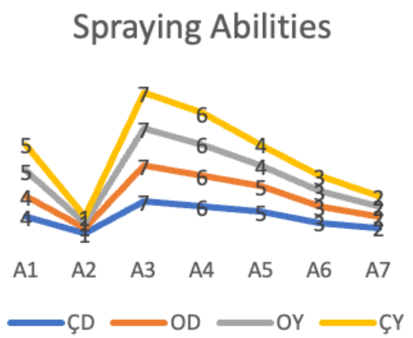

Tank Capacity

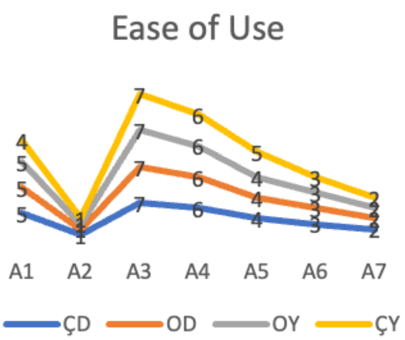

Operational Efficiency

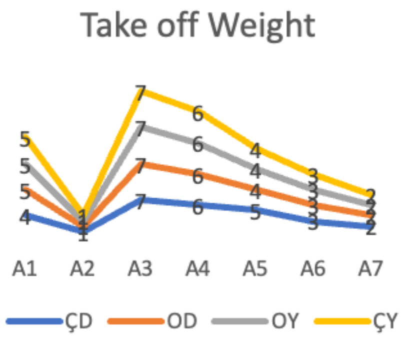

Spraying Speed


Safety


Communication Features


Spraying Abilities


Ease of Use


Take off Weight
5
5
5
4
1
1
1
1
7
7
7
7
6
6
6
6
4
4
4
5
3
3
3
3
2
2
2
2
A1
A2
A3
A4
A5
A6
A7
ÇD
OD
OY
ÇY