Application of the entropy based COPRAS model in determining the most appropriate irrigation systems for agricultural enterprises producing maize

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Abstract

The aim of this study is to determine the most effective irrigation systems for agricultural enterprises producing maize due to decreasing water resources. The study was conducted on 95 agricultural enterprises producing corn in Çumra District of Konya Province. In the study, the importance levels of 10 criteria determined in the decision process were analyzed by Entropy method. The results revealed that the most important criteria are Energy Cost, Labor Requirement and Price, respectively. Irrigation system alternatives were evaluated using the COPRAS method, one of the Multi-Criteria Decision Making (MCDM) methods. In the study, linear irrigation systems were identified as the most suitable irrigation system for the study area. The rapid increase in input costs has led agricultural enterprises to implement cost saving measures. The potential of modern irrigation systems to reduce energy costs has made this criterion a priority factor in irrigation system selection. In this context, the importance of irrigation systems that provide energy efficiency and labor saving plays a critical role for the sustainability of agricultural production.

Keywords: *Maize, Irrigation Systems, MCDM, COPRAS, Entropy.*

1. Introduction

Water is a vital natural resource for living things to survive. However, due to the increasing population and the effects of global warming, water resources are decreasing and access to these resources is becoming increasingly difficult. These challenges cause people to search for ways to save water and develop more efficient water use methods. This necessitates the implementation of more informed and effective strategies for the sustainable management of water. While 97.5% of the world's water is saltwater, only 2.5% is freshwater. Water consumption is distributed in different ways across different areas such as the sustainability of people, animals and natural life, agricultural irrigation, energy production and industrial activities.

Looking at the sectoral distribution of water consumption in the world, 69% of water is used for agricultural activities, 19% for industrial sectors and 12% for drinking water and daily use

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(WWF, 2014). Despite many technological and biological innovations, agriculture is considered one of the most vulnerable sectors to the negative impacts of climate change (Oğuz *et al.*, 2024). If this situation is ignored and the necessary measures are not taken, there is a risk of a serious water crisis in the coming years. In this context, it is of great importance to develop urgent and effective strategies for the efficient management and the conservation of water resources (Özsoy, 2009). In Turkey, 77 % of water (Ministry of Environment, Urbanization and Climate Change, 2023) is used for agricultural irrigation. While the irrigation systems determine how the water is applied to the soil, the irrigation system includes all the tools and equipment necessary to apply these systems (Eryılmaz, 2022). Irrigation systems are an important factor for agricultural development and food security (Haffaf *et al.*, 2021). The high water consumption in agricultural irrigation requires the development of careful strategies for the management and sustainable use of water resources. Planning is necessary in many areas, such as the structure of crops depending on the amount of water, modern irrigation systems, the selection of seeds, the method of tillage and the analysis of plant water needs. The cultivation pattern is of great importance for agricultural businesses because it is both adapted to the climatic conditions and enables high profit margins; as the right product selection supports both efficient production processes and economically sustainable success. The diversity of climatic conditions in Turkey makes it possible to grow different crops in different regions. Precipitation, one of the climatic factors, has a direct impact on the productivity of agricultural activities and the health of ecosystems. The 2023 areal precipitation average in Turkey was 641.5 mm, about 12% above the long-term average (573.4 mm for the 1991-2020 period) (MGM, 2023a). In Konya province, which accounts for 7.86% of Turkey's agricultural area, the average annual precipitation between 1929 and 2023 was 329.7 mm, which is lower than the national average (MGM, 2023b).

Despite the low rainfall in Konya province, farms favour water-intensive crops such as maize, alfalfa, sugar beet and potatoes for reasons of profitability. In 2023, 10.03 million quintals of cereals and 1.85 million quintals of maize were grown in Konya (TurkStat, 2023).

Although cereal crops generally require less water, water-intensive crops such as maize require careful management of water resources and careful planning of irrigation strategies due to the low average rainfall in the region. The water requirement of the maize plant under regional conditions is 788 mm, which is significantly higher than the current amount of precipitation (TAGEM, 2017). This situation emphasizes the importance of water efficiency solutions and effective irrigation systems to increase crop yields and make agricultural production sustainable through the effective use of limited water resources. The research area is one of the driest provinces of Turkey and also constitutes one of the most important grain production areas. Although some studies have discussed the extent to which investments will be made in the products produced in the region (Kaya, 2017; Oğuz and Yener, 2017; Oğuz *et al*., 2024). Since producers are not trained on water use and restrictions, profitability in production comes to the fore. It would be beneficial for the state, universities and local governments to be sensitive about this issue and to provide training to farmers on water scarcity and usage. Otherwise, there will not be much change in the region.

It is important to select suitable irrigation systems for efficient utilization of water resources. Multi-criteria decision making methods (MCDM) are one of the methods used to determine the most suitable irrigation system considering various criteria. Since these methods are able to find the best solution by evaluating different factors, they attract a lot of interest and are widely used. The MCDM method helps to determine the most appropriate option among the available solution alternatives by taking into account multiple criteria (Çiftci, 2024). The impact of MCDM on theories and models that contribute to more systematic and reasonable decision-making processes has increased significantly (Manos *et al.*, 2009). MCDM is an intelligent and effective method that helps decision makers determine the best option according to various criteria (Tian *et al.*, 2023). This approach aims to increase both resource efficiency and support sustainable agriculture as an important tool in optimizing water management and irrigation strategies. In the literature, many studies on water and irrigation systems have conducted comprehensive and effective analyses used MCDM methods. Some of these studies; (Duckstein *et al.*, 1994) and (Raju and Pillai, 1999) used MCDM to evaluate the performance of irrigation systems, (Salgado *et al.*, 2009) evaluated water supply system alternatives with MCDM method, (Sun *et al.*, 2017) used MCDM to evaluate the performance of irrigation systems, (Hosseinzade *et al.*, 2017) proposed a decision-making model to select an appropriate channel structure in the irrigation system, used the Entropy method to determine the weights of the criteria, and the TOPSIS method to rank the alternatives, (Sapkota *et al.*, 2018) evaluated water supply system alternatives with the MCDM method and (Assefa *et al.*, 2018) used the MCDM technique and geographic information system (GIS) to evaluate potentially irrigable areas. (Karleuša *et al.*, 2018) stated that AHP, PROMETHEE and ELECTRE are suitable MCDM methods for decision making on irrigation systems. (Elshaikh *et al.*, 2018) stated that AHP, which is a MCDM method, is one of the four most widely used methods for evaluating irrigation system performance. (Hadelan, 2020) used the AHP method to compare and rank three possible locations for constructing an irrigation system in different regions of Croatia. (Karleuša *et al.*, 2019) used MCDM to solve various water management problems. (Veisi, 2022) used the AHP method in sustainable water management by developing a set of indicators to determine the most suitable irrigation system that has an impact on agricultural sustainability. (Tork *et al.*, 2021) used the AHP and COPRAS methods for weighting and ranking criteria for the modernization of the surface water distribution system.

The aim of this study is to determine the most effective method among the irrigation systems of the enterprises producing maize and to determine the weights of the criteria that are effective in choosing this method and to make policy recommendations according to these results. The COPRAS method, one of the MCDM methods, was used in determining the irrigation system preferences of the agricultural enterprises producing maize in the Çumra district of Konya province. The Entropy method was preferred in the weighting of the criteria in the mentioned method. This approach provides a comprehensive analysis to evaluate the efficiency of irrigation systems and to select the most appropriate system.

2. Material and methods

Primary data were used in the study and these data were collected using survey technique. The data were collected at the end of the 2024 harvest and were obtained by the researcher himself. Çumra district of Konya province was selected as the research area. The reason for choosing this district is that it ranks first in maize production in Konya province. While maize production is carried out in a total area of 185,505 hectares in Konya province, 35.20% of this area, that is, 35,200 hectares, is in Çumra district (TurkStat, 2023). By using these data, a total of 6000 maize producing enterprises were identified for the main sampling frame in the region. It emphasizes the share and importance of Çumra in maize production. The research data were obtained using survey technique and the surveys were conducted face to face with agricultural enterprises producing maize on a voluntary basis.

In the study, the sample size volume was calculated according to the formula below using simple random probability sampling based on finite main population ratios (Miran, 2003; Oğuz & Karakayacı, 2017).

$$n = \frac{N \times p \times (1-p)}{(N-1) \times \sigma^2_{p^x} + p \times (1-p)} \qquad (1)$$

Formula;

n= Sample volume

N= Number of maize producing agricultural enterprises in the sampling frame (6000 units)

$\sigma^2_{p^x}$ = Variance

p=0.50

q=1-p

Using the formula in Equation (1), the sample volume was calculated as 95 with a 10% margin of error and 95% confidence interval.

2.1. The methods applied in the selection of the most appropriate irrigation systems for maize production enterprises

In order to determine the decision-making factors that are important in the selection of irrigation systems to be used in maize production, the opinions of corn (grain) producers as well as subject matter experts working in universities, public institutions and other organisations were taken. In addition, other studies conducted in the study area were also utilized. In a study conducted in Çumra district of Konya province, it was reported that 85% of the producers used sprinkler and drip irrigation methods (Kaya, 2017). In another study conducted in the same region, it was stated that sprinkler, drip irrigation, circular moving irrigation and linear moving irrigation systems were widely used for 9 different crops and the internal profitability of these systems were calculated (Ağızan, 2018). In another study conducted by Oğuz *et al.* (2021) in Çumra district, it was revealed that the rate of adoption of innovations in modern irrigation systems by producers was high, and the effects of sprinkler irrigation, drip irrigation and pivot irrigation systems on yield and profitability in corn production were determined. The aim of this process was to better understand the factors that will increase the effectiveness and efficiency of irrigation systems and to offer the most appropriate options to producers. The data obtained in this context will help to make informed and effective decisions on the selection of irrigation systems. The 10 criteria to be considered in the selection of irrigation systems were determined as brand, price, quality, product type, durability, labour requirement, economic life, energy cost, service facility and water saving. These criteria were evaluated on a 7-point scale (Very Poor (1), Poor (2), Somewhat Poor (3), Medium (4), Somewhat Good (5), Good (6) and Very Good (7)) for 5 alternative irrigation systems namely Sprinkler Irrigation, Drip Irrigation, Pivot Irrigation, Linear Irrigation and Drum Irrigation. COPRAS method was used to select the most appropriate irrigation system and entropy method was used to weight the criteria. These methods are given below.

2.1.1. *Entropy Method*

The entropy theory developed by Shannon in 1948 emphasizes that the quality and quantity of information in decision-making processes play a critical role in determining correct and reliable solutions. According to the entropy theory, the amount of information available determines the effectiveness in solving the problem and is a tool used to realize different evaluation situations in the decision-making process and helps to measure the amount of information provided (Wu *et al.*, 2011). The entropy method is not based on the subjective judgement of decision makers; instead, it functions as an objective weighting method and usually consists of five stages.

Step 1 - Determining the decision matrix: To construct the decision matrix, if you have k selection criteria and l alternatives, this matrix is usually presented with k criteria organized as columns and l alternatives as rows. In the matrix, x_{ij}, represents the performance value of the i. alternative according to the j. criterion.

$$A_{ij} = \begin{bmatrix} x_{11} & x_{12} & \dots & x_{1k} \\ x_{21} & x_{22} & \dots & x_{2k} \\ \vdots & \vdots & \vdots & \vdots \\ x_{l1} & x_{l2} & \dots & x_{lk} \end{bmatrix} \quad (2)$$

In the study, 10 (k=10) criteria (brand, price, quality, product type, durability, labour requirement, economic life, energy cost, serviceability and water saving) and 5 (l=5) alternatives (sprinkler irrigation, drip irrigation, pivot irrigation, linear irrigation and drum irrigation) were determined.

Step 2 - Decision Matrix Normalisation: In order to use different scale dimensions together, the initial matrix elements need to be standardized. This is done by using Equation (3) for normalisation of benefit-based criteria and Equation (4) for normalisation of cost-based criteria. These standardization steps ensure comparability of data at different scales.

$$r_{ij} = \frac{x_{ij}}{\max\limits_{j} x_{ij}} \quad \left(i = 1, 2, \dots, l; j = 1, 2, \dots, k\right) \quad (3)$$

$$r_{ij} = \frac{\min\limits_{j} x_{ij}}{\underset{j}{x_{ij}}}, \ \min_{j} x_{ij} \neq 0 \ \left(i = 1, 2, \dots, l; j = 1, 2, \dots, k\right) \quad (4)$$

i = Alternative value,
j = Criterion value,
r_{ij} = Normalized value.

After the indices are standardized, they are shown in the normalized index matrix $R = \left[r_{ij} \right]_{l \times k}$.

In this study, while normalizing the decision matrix for weighting the criteria, price and energy cost criteria were determined as cost criteria. On the other hand, brand, quality, product type, durability, labour requirement, economic life, serviceability and water saving criteria were considered as benefit criteria.

Step 3 - Calculation of Entropy: In this step, first the values are calculated using Equation 5,

$$f_{ij} = \frac{r_{ij}}{\sum_{i=1}^{l} r_{ij}} \tag{5}$$

The values obtained in Equation (5) are used in Equation (6) to calculate the entropy value for each criterion. In this formula t; $t=1/\ln(m)$ the constant value used represents a value obtained by a specific calculation method.

$$e_j = -t \sum_{j=1}^{k} f_{ij} . \ln f_{ij} \quad \left(i = 1,2,...,l; j = 1,2,...,k \right) \tag{6}$$

Since there are 5 decision alternatives in the above equation, the value of m is determined as 5. By substituting this value in the formula, the t value was calculated and used in Equation (6) as $t=1/\ln(5)=0.621$.

Step 4 - Determining the entropy weight of the criteria: The magnitude of the entropy weight of the criteria indicates how effective that criterion is in the decision-making process and clarifies the importance of each criterion in the decision-making process. These weights were determined by calculating as specified in Equation (7).

$$w_j = \frac{1 - e_j}{\sum_{j=1}^{k} \left(1 - e_j \right)}, \ \sum_{j=1}^{k} w_j = 1, \ \left(j = 1,...,k \right) \tag{7}$$

w_j = Weight value,
e_j = Entropy value.

The entropy method is an evaluation method that can be easily applied by calculations made directly on the data, independent of subjective evaluations, and provides completely objective results, and the criteria weights obtained from this method are then used in the COPRAS method.

2.1.2. *COPRAS Method*

The COPRAS (COmplex PRoportional ASsessment) method, developed by Zavadskas *et al.* in 1994, helps to determine the most appropriate option by providing an effective comparison of alternatives in multi-criteria decision-making problems. The method determines the appropriate solution by calculating the direct and indirect ratios of each alternative with the best and worst solutions while choosing the best one among many alternatives (Yücenur *et al.*, 2019). The basic calculation steps of the COPRAS method are as follows (Zolfani *et al.*, 2018).

Step 1: When constructing the decision matrix, if there are k selection criteria and l alternatives, this matrix is usually presented with k criteria organized as columns and l alternatives as rows. In the matrix a_{ij}, the performance value of the i. alternative according to the j. criterion is represented.

$$A = \left[a_{ij} \right]_{l \times k} = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1k} \\ a_{21} & a_{22} & \cdots & a_{2k} \\ \vdots & \vdots & \vdots & \vdots \\ a_{l1} & a_{l2} & \cdots & a_{lk} \end{bmatrix} \tag{8}$$

Step 2 - Constructing the Standardized Decision Matrix: After the decision matrix A is obtained, the normalization process is performed using equation (9) and the normalized decision matrix $\bar{A}$ specified in equation (10) is reached.

$$\bar{a}_{ij} = \frac{a_{ij}}{\sum_{i=1}^{l} a_{ij}} \quad \left(i = 1,2,...,l; j = 1,2,...,k \right) \tag{9}$$

i = Alternative value,
j = Criterion value,
$\bar{a}_{ij}$ = Normalized value.

$$\bar{A} = \left[\bar{a}_{ij} \right]_{l \times k} = \begin{bmatrix} \bar{a}_{11} & \bar{a}_{12} & \cdots & \bar{a}_{1k} \\ \bar{a}_{21} & \bar{a}_{22} & \cdots & \bar{a}_{2k} \\ \vdots & \vdots & \vdots & \vdots \\ \bar{a}_{l1} & \bar{a}_{l2} & \cdots & \bar{a}_{lk} \end{bmatrix}$$

$$\left(i = 1,2,...,l; j = 1,2,...,k \right) \tag{10}$$

Step 3 - Constructing the Weighted Standardized Decision Matrix: Each element of the decision matrix standardized by Equation (11) is multiplied by the relevant criteria weights. This is done to obtain the weighted performance values of each alternative with respect to the criteria.

$$\hat{a}_{ij} = \bar{a}_{ij} \times w_j \tag{11}$$

After this process is completed, the $\hat{A}$ weighted standardized decision matrix is obtained as shown in Equation (12).

$$\hat{A} = \left[\hat{a}_{ij}\right]_{l \times k} = \begin{bmatrix} \hat{a}_{11} & \hat{a}_{12} & \cdots & \hat{a}_{1k} \\ \hat{a}_{21} & \hat{a}_{22} & \cdots & \hat{a}_{2k} \\ \vdots & \vdots & \vdots & \vdots \\ \hat{a}_{l1} & \hat{a}_{l2} & \cdots & \hat{a}_{lk} \end{bmatrix}$$

$$\left(i = 1, 2, \ldots, l;\, j = 1, 2, \ldots, k\right) \tag{12}$$

In the study, a weighted standardized decision matrix was obtained by using the criteria weights obtained by Entropy method.

Step 4 - Calculation of S_{+1} and S_{-1} values: According to whether the criteria are of benefit or cost type, the total weighted standardized values are calculated by S_{+1} and S_{-1}. Here, S_{+1} represents the sum of benefit criteria and S_{-1} represents the sum of cost criteria. With the help of Equations (13) and (14), $\hat{a}_{+ij}$ and $\hat{a}_{-ij}$ represent the performance values with benefit and cost criteria, respectively.

$$S_{+i} = \sum_{j=1}^{v} \hat{a}_{+ij} \quad \left(i = 1, 2, \ldots, l;\, j = 1, 2, \ldots, v\right) \tag{13}$$

$$S_{-i} = \sum_{j=1}^{k} \hat{a}_{-ij} \quad \left(i = 1, 2, \ldots, l;\, j = 1, 2, \ldots, k\right) \tag{14}$$

Step 5 - Calculation of Relative Importance values: The relative importance value Q_i of the i. alternative is calculated using equation (15) and this value reflects the level of satisfaction achieved by the alternative. A higher value of Q_i indicates that the alternative is closer to the ideal alternative. Each alternative has a value between 0 and 100 per cent.

$$Q_i = S_{+i} + \frac{\sum_{i=1}^{l} S_{-i}}{S_{-i} \times \sum_{i=1}^{l} \frac{1}{S_{-i}}} \tag{15}$$

Step 6 - Calculation of performance index values and obtaining rankings: The performance index value is calculated by dividing the Q_i value of each alternative by the maximum Q_i value. The proportional similarity of any alternative to the ideal alternative is found in this step.

$$P_i = \left[\frac{Q_i}{Q_{\max}}\right] \times 100\% \quad \left(i = 1, 2, \ldots, l\right) \tag{16}$$

Finally, the preference ranking of the alternatives is determined by ranking the calculated P_i values from largest to smallest.

3. Research findings and discussion

At this stage of the study, irrigation systems were evaluated and ranked according to the criteria determined by using the Entropy and COPRAS methods. Firstly, an initial decision matrix was formed by taking the arithmetic mean of the scores given for each criterion for the determination of irrigation systems in maize producing enterprises. In the next step, the importance coefficients of the criteria were calculated with the Entropy method and the ranking of the irrigation systems was carried out with the COPRAS method. Calculations were made in Microsoft Excel.

3.1. *Obtaining Criteria Weights with Entropy*

Step 1 - Creating the Decision Matrix: In the construction of the decision matrix; the answers of 95 agricultural enterprises for each criterion were summed and averaged and the decision matrix in Table 1 was obtained.

Step 2 - Decision Matrix Normalization: The values determined as cost criteria are standardized by dividing by the maximum value. Other values determined as benefit criteria were normalized by dividing by the minimum value. The standardized values obtained are presented in Table 2.

The rows of the standardized values of the decision matrix contain the evaluation criteria and the columns contain the decision alternatives.

Table 1 - Decision Matrix for irrigation system.

CRITERIA	*Irrigation System*						
	Sprinkler Irrigation	*Drip Irrigation*	*Pivot Irrigation*	*Linear Irrigation*	*Drum Irrigation*	*Max*	*Min*
Brand	4	4,4	5,2	5,7	5,2	5,7	4
Price	3,5	3,8	5,6	5,7	6	6	3,5
Quality	3,7	3,9	5,2	6,1	5,2	6,1	3,7
Product Type	4,9	5	4,9	5	4,8	5	4,8
Durability	3,6	3,5	5,2	5,8	5,4	5,8	3,5
Labour Requirement	2,9	5,1	6,2	6,8	6,2	6,8	2,9
Economic Life	3,4	3,2	5	5,1	4,9	5,1	3,2
Energy Cost	4,6	2,9	1,6	1,3	1,6	4,6	1,3
Service Facility	4,5	4,6	4,8	4,8	4,8	4,8	4,5
Water Saving	3,8	5,1	6,1	7	6	7	3,8

Table 2 - Standardized values for irrigation system.

CRITERIA	*Irrigation System*					*Total*
	Sprinkler Irrigation	*Drip Irrigation*	*Pivot Irrigation*	*Linear Irrigation*	*Drum Irrigation*	
Brand	0,701	0,771	0,912	1,000	0,912	4,298
Price	1,000	0,921	0,625	0,614	0,583	3,743
Quality	0,606	0,639	0,852	1,000	0,852	3,951
Product Type	0,980	1,000	1,000	0,980	0,960	4,920
Durability	0,621	0,603	0,896	1,000	0,931	4,051
Labour Requirement	0,426	0,750	0,911	1,000	0,911	4,000
Economic Life	0,666	0,627	1,000	0.981	0,961	4,235
Energy Cost	0,282	0,448	0,812	1,000	0,812	3,355
Service Facility	0,937	0,958	1,000	1,000	1,000	4,895833
Water Saving	0,542	0,728	0,871	1,000	0,857	4,000

Step 3 - Calculation of entropy: In this step, f_{ij} is first normalized using equation (4). These values can be seen as the re-standardization of the standardized matrix elements. When calculating the values, the values in each row in Table 2 are normalized by dividing them by the sum of the rows to which they belong. The decision matrix obtained after normalization is shown in Table 3.

Then $\ln f_{ij}$ is obtained for the realisation of the operations in Equation (5). After calculating this value, $f_{ij} \times \ln f_{ij}$ is found. Moreover, the k value in Equation (5) is the entropy coefficient and represents the logarithmic form of the number of alternatives in the decision matrix. The entropy values (e_{ij}) obtained with the help of Equation (5) are presented in Table 4.

Step 4 - Calculation of entropy weight: Using the entropy values (e_{ij}) obtained in Equation (5), the weight value for each criterion obtained in Equation (6) is obtained in Table 4.

The obtained weight values (w_i) will be used as weight values in the COPRAS method to be used in irrigation system selection. While selecting the most suitable irrigation system in the study, the standardized values in Table 3 were calculated by using the pairwise

Table 3 - Normalized decision matrix.

CRITERIA	*Irrigation System*				
	Sprinkler Irrigation	*Drip Irrigation*	*Pivot Irrigation*	*Linear Irrigation*	*Drum Irrigation*
Brand	0,163	0,179	0,212	0,232	0,212
Price	0,267	0,246	0,166	0,164	0,155
Quality	0,153	0,161	0,215	0,253	0,215
Product Type	0,199	0,203	0,203	0,199	0,195
Durability	0,153	0,148	0,221	0,246	0,229
Labour Requirement	0,106	0,187	0,227	0,250	0,227
Economic Life	0,157	0,148	0,236	0,231	0,226
Energy Cost	0,084	0,133	0,242	0,297	0,242
Service Facility	0,191	0,195	0,204	0,204	0,204
Water Saving	0,135	0,182	0,217	0,250	0,214

Table 4 - Entropy and weight values of the criteria.

Criteria	*Brand*	*Price*	*Quality*	*Product Type*	*Durability*	*Labour Requirement*	*Economic Lifetime*	*Energy Cost*	*Service Facility*	*Water Saving*
e_{ij}	0,995	0,983	0,989	0,999	0,986	0,977	0,987	0,947	0,999	0,987
w_i	0,033	0,114	0,074	0,0004	0,091	0,154	0,0831	0,361	0,002	0,0835

comparison matrix in Table 1 and the weights were determined by using the Entropy values in Table 4. According to the data obtained in Table 4, it was determined that the most important criterion in irrigation system selection was 'Energy Cost' with a weight of 36.16%. The increase in agricultural production and the development of agricultural technology have increased the need and demand for energy all over the world (Moghaddasi and Pour, 2016). Energy consumption has increased with the effect of increasing demand, especially with the use of fossil fuels, bringing both economic and environmental challenges. As a matter of fact, in addition to preventing environmental pollution by reducing the consumption of fossil fuels, it has become a necessity to use energy effectively and efficiently in agriculture in order to save energy and reduce input costs (Mohammedi *et al.*, 2008). When modern irrigation systems are designed for energy efficiency, they can provide lower energy costs and better performance. This can benefit both economically and environmentally. Keeping energy costs low allows farmers to sell their products at more competitive prices and increase profits. Furthermore, energy sources used for agricultural irrigation are limited and can be difficult or costly to access in some regions. Therefore, energy efficiency and cost are critical to the sustainability of the irrigation system.

After the Energy Cost criterion, 'Labour Requirement' ranks second and has an impact of 15.49% in decision making. Systems that require more labour often require more time and effort, and in recent years there have been difficulties in accessing sufficient and skilled labour. The average age in agricultural enterprises is increasing day by day. The decrease in the number of people participating in the labour force in rural areas, the increase in migration from rural to urban areas, finding temporary workers due to the intermittent nature of agricultural production, and the inadequate wages of workers have led enterprises to employ migrant and asylum-seeker workers (Fuglie, 2018). As a matter of fact, these problems play an important role in the fact that labour requirement takes the second place in the criteria weighting. Automated irrigation sys-

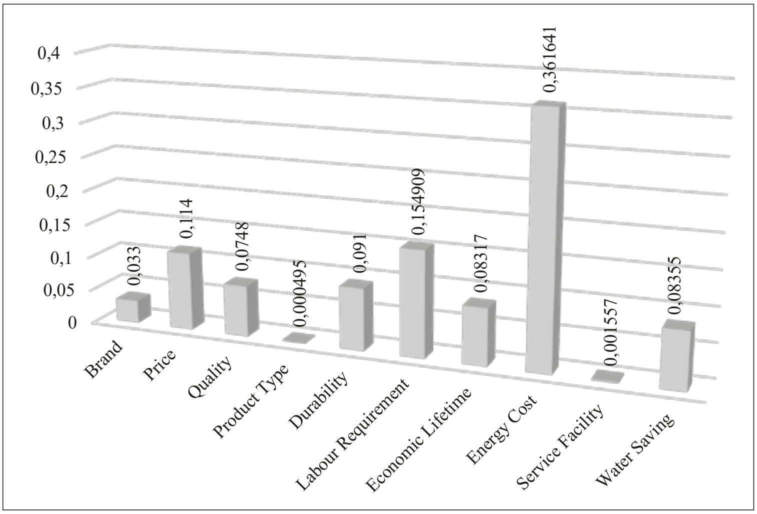

Figure 1 - Importance weights of criteria and their place in the rankings.

tems used to reduce labour requirements generally require less manpower, which reduces operating costs. Automation can make irrigation processes more efficient by minimising the need for labour.

Among the decision criteria, 'Price' criterion ranks third with a weight of 11.43%. It is an expected result that the price ranks third in the preference criteria of the enterprises to increase the level of equipment. Agricultural enterprises usually work with limited budgets and price directly influences the choice of an irrigation system by the agricultural enterprise. Price influences farmers or agribusinesses to choose according to their initial investment budget. An affordable system can shorten the return on investment period and reduce start-up costs. Especially for small-scale enterprises, investment cost is very important in terms of sustainability. In countries where small-scale agricultural enterprises are widespread, it is necessary to meet capital needs from foreign sources (Işıklı *et al.*, 1994). Investment in tools and equipment in agriculture is critical to increase productivity and optimise the workforce. However, price plays a major role in these investments, not only in terms of initial cost, but also in terms of long-term productivity and cost-effectiveness. High quality and correctly priced equipment can save time and labour at every stage of the farming process. In addition, choosing affordable yet reliable equipment can reduce the total cost of ownership by minimising maintenance and repair costs. Therefore, price is a strategic factor in agricultural equipment investments in terms of both initial expenditure and long-term economic efficiency. As a matter of fact, price is very important in terms of investment cost, product performance, operating profitability balance and sustainability.

In other criteria, 'Durability' ranks fourth with 9.16%, 'Water Saving' ranks fifth with 8.35%, 'Economic Life' ranks sixth with 8.31%, 'Quality' ranks seventh with 7.47%, 'Brand' ranks eighth with 3.39%, 'Service Facility' ranks ninth with 0.15% and 'Product Type' ranks last with 0.04%. In the study region, where the severity of drought has increased due to climate change, a significant withdrawal of groundwater is observed. (Chebil *et al.*, 2024), in a study conducted in Tunisia, found that providing training on new technologies and water saving, providing financial support and incentives contributed to early adoption by providing access to these technologies.

As seen in Figure 1, the importance weights of the 10 criteria are listed as follows: Energy Cost > Labour Requirement > Price > Durability > Water Saving > Economic Life > Quality > Brand > Service Facility > Product Type. The sum of the weight values assigned to each of these criteria is equal to 1. This ranking shows the relative importance of each criterion in the total evaluation.

3.2. *Irrigation Systems Ranking with COPRAS Method*

Step 1 - Creating the Decision Matrix: In the first step of the COPRAS method, the decision matrix is created. This step is the same as the first step of the Entropy method. The values in Table 1 will also be used in the COPRAS method.

Step 2 - Constructing the Normalized Decision Matrix (R): Equation (8) in the COPRAS method was used in the normalization process to convert the criterion values of the alternatives into fixed units. The normalized decision matrix is shown in Table 5.

Step 3 - Constructing the Weighted Normalised Decision Matrix: The weighted normalized decision matrix in Table 6 was obtained by multiplying each *i.*alternative value over the normalized decision matrix in Table 5 by the criteria weights determined in Table 4 obtained in the last step of the Entropy method.

Step 4 - Obtaining S_{+1} and S_{-1} values: In this step, the total weighted standardized values of the decision alternatives according to whether the criteria are of benefit or cost type are calculated using Equation (12) and Equation (13). The solution sets obtained as a result of the calculations are presented in Table 7.

Table 5 - Normalized decision matrix according to COPRAS method.

CRITERIA	*Irrigation System*				
	Sprinkler Irrigation	*Drip Irrigation*	*Pivot Irrigation*	*Linear Irrigation*	*Drum Irrigation*
Brand	0,163265	0,179592	0,212245	0,232653	0,212245
Price	0,142276	0,154472	0,227642	0,231707	0,243902
Quality	0,153527	0,161826	0,215768	0,253112	0,215768
Product Type	0,199187	0,203252	0,199187	0,203252	0,195122
Durability	0,153191	0,148936	0,221277	0,246809	0,229787
Labour Requirement	0,106618	0,1875	0,227941	0,25	0,227941
Economic Life	0,157407	0,148148	0,231481	0,236111	0,226852
Energy Cost	0,383333	0,241667	0,133333	0,108333	0,133333
Service Facility	0,191489	0,195745	0,204255	0,204255	0,204255
Water Saving	0,135714	0,182143	0,217857	0,25	0,214286

Table 6 - Weighted normalized decision matrix values.

CRITERIA	*Irrigation System*				
	Sprinkler Irrigation	*Drip Irrigation*	*Pivot Irrigation*	*Linear Irrigation*	*Drum Irrigation*
Brand	0,00552	0,006072	0,007176	0,007867	0,007176
Price	0,01619	0,017578	0,025904	0,026367	0,027755
Quality	0,011423	0,01204	0,016054	0,018832	0,016054
Product Type	9,82E-05	0,0001	9,82E-05	0,0001	9,62E-05
Durability	0,013965	0,013578	0,020172	0,0225	0,020948
Labour Requirement	0,016437	0,028907	0,035141	0,038542	0,035141
Economic Life	0,013781	0,012971	0,020267	0,020672	0,019861
Energy Cost	0,137966	0,086979	0,047988	0,038991	0,047988
Service Facility	0,000297	0,000303	0,000316	0,000316	0,000316
Water Saving	0,011285	0,015145	0,018115	0,020788	0,017818

Step 5 - Calculation of Relative Importance Values: In this step, the relative importance value of the *i*. alternative, Q_i, is calculated using Equality (14). The obtained Q_i value is shown in Table 8.

Step 6 - Calculation of performance index values and obtaining rankings: In the last step of the COPRAS method, the performance index value of each alternative is calculated. This value is obtained by dividing the Q_i value of each alternative by the highest Q_i value and is expressed using Equality (15). The P_i performance index values obtained as a result of the application are presented in Table 8.

As seen in Table 8, the system with the highest performance index score is linear irrigation. The linear irrigation system is followed by pivot irrigation with 89.51 in the second place, drum irrigation with 88.47 in the third place, drip irrigation with 65.69 in the fourth place and sprinkler irrigation with 49.41 in the last place. The results obtained in Table 8 support the findings of Neisi *et al.* (2020) and determined that linear and drip irrigation systems were generally the most suitable systems. In addition, Veisi *et al.* (2022) emphasized that pressurized irrigation systems are the best systems for developing sustainable water management in agriculture. Bigdeli (2021) revealed that the linear irrigation system is more effective than the wheel-moving (pivot) irrigation system in terms of water distribution in different climatic conditions. Rahmani *et al.* (2017) stated that pressurized irrigation systems can be an effective technology for improving production and reducing input costs by reducing water consumption by 17%.

The data obtained as a result of the survey conducted with agricultural enterprises in the study area were analyzed using the COPRAS method. As a result, the order of preference among irrigation system alternatives was determined as Linear Irrigation > Pivot Irrigation > Drum Irrigation > Drip Irrigation > Sprinkler Irrigation (Figure 2).

In the study, it was determined that modern irrigation systems are widely used. It has been determined that agricultural enterprises in the research region are open to innovations and are aware of the contributions of modern irrigation

Table 7 - S_{+1} and S_{-1} values of alternatives.

Irrigation System	S_{+1}	S_{-1}
Sprinkler Irrigation	0,07280	0,15415
Drip Irrigation	0,08911	0,10455
Pivot Irrigation	0,11734	0,07389
Linear Irrigation	0,12961	0,06535
Drum Irrigation	0,11741	0,07574

Figure 2 - Score obtained according to the COPRAS method (%).

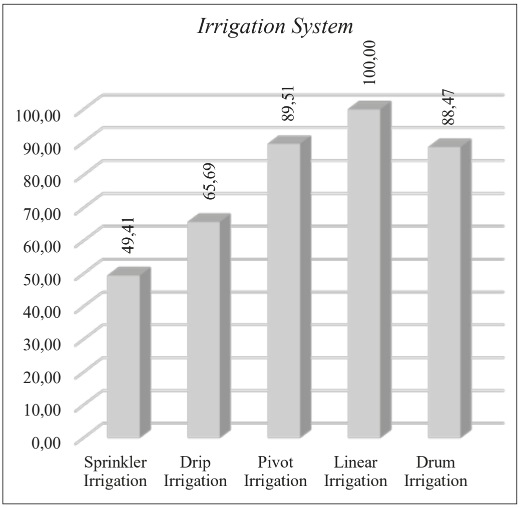

Table 8 - Alternatives Q_i, scores and rankings.

Irrigation System	S_{+1}	S_{-1}	$1/S_{-1}$	Q_i	P_i	*Ranking*
Sprinkler Irrigation	0,072807	0,154157	6,486907	0,125708	49.41	5
Drip Irrigation	0,089117	0,104557	9,56418	0,167113	65.69	4
Pivot Irrigation	0,11734	0,073893	13,53314	0,227704	89.51	2
Linear Irrigation	0,129617	0,065357	15,30048	0,254394	100	1
Drum Irrigation	0,117412	0,075743	13,20255	0,22508	88.47	3

systems to energy, water and labor efficiency. The fact that these systems ensure the effective use of water resources and reduce input costs has made a significant contribution to increasing the awareness of producers. Additionally, it has been stated that modern irrigation systems increase the profitability of businesses by reducing input costs (Oğuz *et al.*, 2021). Factors such as the increase in the average age in agricultural enterprises, the problem of finding foreign labor, energy costs, the closed basin of the region and the decrease in groundwater in recent years have played an important role in the spread of modern irrigation methods.

4. Conclusions and recommendations

In recent years, increasing competition conditions, developing seed technology, deepening of the current labor force problem in agriculture with the increase in the average age of enterprises, drought that has increased in severity with the effect of climate change, increase in input costs, technological developments in equipment and machinery used in agriculture, equipment and machinery incentives of the Ministry of Agriculture and Forestry, subsidized loans of banks have made significant contributions to the development of technology usage level of enterprises. In the recent period, the provision of some supports on the condition of economical irrigation systems has been an important factor in preferring modern irrigation systems. It is known that certain criteria as well as the capital power of enterprises play a role in the preference of these systems. Therefore, the MCDM model has been proposed in this study in order to determine the important factors in the selection of irrigation systems for agricultural enterprises.

In the first stage, criteria for irrigation system selection were determined by literature review, then ten criteria were included in the study based on expert opinions. The Entropy method was used to determine the weights of the criteria and irrigation systems were evaluated with COPRAS method. The findings show that energy cost ranks first and labor requirement ranks second in the order of weight of irrigation system criteria. According to the study results, it was understood that the most preferred system among the determined irrigation systems is the linear irrigation system.

The most important criterion in determining the criteria affecting irrigation systems was determined to be energy cost. The rapid increase in input costs and the increase in energy costs forced operators to take saving measures. The potential of modern irrigation systems to reduce energy costs has made this criterion a priority factor in irrigation system selection. At the same time, the fact that these systems minimize the need for human labor has been determined as the second choice criterion for labor. In regions where maize is cultivated intensively due to its high profitability, the fact that these two basic criteria are at the forefront and the linear irrigation system stands out as the most preferred system shows that the Ministry of Agriculture and Forestry's increasing incentives to support this area and the banks' offering subsidized loans to these systems are critical for the sustainability of production in the study region. In addition, since the requirement of only drip irrigation in the maize Differential Payment Support of the Ministry of Agriculture and Forestry and the fact that producers who irrigate with pivot irrigation systems are not allowed to benefit from the support restricts the use of this modern irrigation system, it is thought that the scope should be expanded and producers who irrigate with pivot (pivot, linear, drum) irrigation systems should also benefit from the differential payment support. It is noteworthy that water saving ranks fifth among the criteria; irregularities in rainfall and the decrease in groundwater require producers to be more careful in this regard. Farmers who grow grain, sugar beet, carrot, sunflower and forage crops for cattle in the region should be trained on water conservation and use, and the region's water availability should be taken into account within the scope of production planning. It is recommended that the Ministry of Agriculture and Forestry switch to a planned production model starting from the 2025 production season, and that irrigation systems that will save water be expanded in the study area, which is in the water constraint region, and that more farmer meetings, public service announcements and symposiums be organized to raise awareness among producers.

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