

Ranking Of Inorganic And Organic Fertilizer Using Multi Criteria Decision Making: TOPSIS Approach

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ABSTRACT

The study utilizes the 'Technique for Order Preference by Similarity to Ideal Solution' (TOPSIS), a well-established Multi-Criteria Decision-Making (MCDM) methodology, to systematically evaluate and rank the suitability of organic and inorganic fertilizers for agricultural use in Sangamner Tehsil, District Ahilyanagar, Maharashtra, India. The evaluation framework incorporates six critical criteria: availability of the fertilizer, cost-effectiveness, crop yield potential, and its impacts on human health, soil quality, and the broader environment. By applying the TOPSIS technique, which identifies the best option based on its proximity to an ideal solution, the analysis revealed that organic fertilizers achieved a higher relative closeness score of 0.674088, indicating a preferable overall performance. This decision-support approach equips farmers with a rational, data-driven tool to guide fertilizer selection, thereby minimizing dependence on potentially biased information from commercial vendors or local agents. Moreover, the findings underscore the potential of the TOPSIS model in promoting more sustainable, health-conscious, and environmentally responsible farming decisions. By incorporating both qualitative and quantitative factors into the evaluation process, this study contributes to the broader discourse on sustainable agriculture and offers a replicable model for other regions facing similar challenges.

Keywords: Mcdm, Ahp, Topsis, Vikor, Electre, Promethee, Saw.

1.0 INTRODUCTION

Fertilizer selection is an important aspect of agricultural economy. Fertilizers serve multiple purposes to enhance soil quality, including improving soil structure, water retention, fertility, and nutrient content as well as boosting crop production. However, the use of unsuitable fertilizers can have detrimental effects on soil fertility, ultimately leading to a decline in the economic wellbeing of farmers. With limited resources, it is challenging to make judicious decisions based on the number of existing alternatives and interdependent criteria.

The primary aim of this research was to offer a well-considered choice for ranking inorganic and organic fertilizers, using the TOPSIS method with six available criteria: fertilizer availability (FA), fertilizer cost (FC), yield (Y), fertilizer impact on human health (FH), soil (ES), and environment (EE). The suggested methods were used to make judicious decisions. MCDM methods are classified into MADM and MODM methods, which are further classified into MAVT, MAUT, SAW, AHP, ANP, TOPSIS, ELCTRE, and PROMETHEE methods, which are classified into mathematical model applications such as LP, NLP, GP, and CP. Each method has applications in various fields such as structural applications, transportation, logistics, agriculture, industry, finance, business, chemical engineering, energy management, and irrigation. A case study was conducted to rank the effectiveness of organic and inorganic fertilizers using farmers from Nimgaon Bhojapur Village in Maharashtra. The village is located at latitude 19.62158 and longitude 74.13609, within the Sangamner tehsil of Ahilyanagar district. Multiple MCDM methods have already been used in various fields, as mentioned above. Each method has its advantages, disadvantages, and applications.

The TOPSIS method is used extensively across various domains, including energy sector management, transport systems, healthcare, safety protocols, logistics operations, medical practices, educational systems, environmental management, human resource administration, irrigation planning, supply chain operations,

and chemical engineering processes. Hwang and Yoon developed the TOPSIS method in 1981. Raju and Kumar (1999) proposed the innovative MCDM method PROMETHEE-2 and advanced method EXPROM-2 for irrigation planning and management [22]. Yong (2006) used fuzzy TOPSIS to select a location for building a new plant [30]. Jahanshahloo, lofti, and Izadikhah (2006) compare the 15 banks based on their financial ratios using TOPSIS interval data [12]. Rahimi et al. (2007) used a modified TOPSIS method to evaluate patient medical information in a medical diagnostic system [21]. Shih, Shyur, and Lee (2007) proposed the extended TOPSIS method for recruiting an online manager in a chemical company [26]. Sandra et al. (2007) used the MCDM method in the transportation industry [24].

Amiri et al. (2009) proposed a fuzzy approach, linear assignment method, genetic algorithm, adaptive AHP approach, and TOPSIS method to rank competing firms based on their performance [2]. Chu and Lin (2009) used the F-TOPSIS method to solve the facility site selection problem [7]. Wang (2011) used the F-TOPSIS method [29]. Chang, Lin, and Chiang (2010) proposed the TOPSIS method to evaluate the performance of 82 Taiwanese mutual funds over thirty-four consecutive months [6]. Roghanian et al., Rahimi et al., and Ansari (2010) proposed F-TOPSIS to select a suitable material supplier to purchase key components for new products [23]. Regulwar (2012) used a Multi- MOFLP model for irrigation planning [9]. Montazar et al. (2013) used the F-AHP method [18]. Sustainable renewable energy development Kumar et al. (2017) proposed the MCDM model [16]. In 2018, Ligus and Peternek applied the F-AHP and F-TOPSIS methodologies to identify the most appropriate low-emission energy technologies for Poland. Karleusa (2019) proposed the MCA method [14]. In the environmental engineering field Hwang and Liu (1993), Assari et al. (2012), Basset et al. (2021), and Zolfaghary et al. (2021) used various MCDM methods [11,3,4,31]. AIMallahi et al.(2022) proposed the AHP TOPSIS method to evaluate a solar desalination unit. The author used seven criteria for evaluation: quality, eco-friendliness, convenience, durability, size, long duration, and cost [1]. Jing et al. (2024) studied the DPSIR-entropy weight TOPSIS model to analyze obstacle factors in the spatiotemporal evaluation of the ecological security of cultivated land [13]. Kefe et al.(2024) used the entropy-based TOPSIS method to evaluate financial performance [15]. Mitra et al. (2023) proposed the TOPSIS method for flood susceptibility mapping using Microsoft Excel and Geographic Information System. The authors suggested that integration of the TOPSIS method GIS provided good results for flood susceptibility mapping [19]. Han et al.(2024) used TOPSIS and Fuzzy TOPSIS methods to evaluate sustainable water management [10]. Three alternatives (rainwater harvesting, water recycling, and desalination) and five criteria (water efficiency, cost-effectiveness, social equity, environmental impact, and technological feasibility) were evaluated. The results indicate that rainwater harvesting was the most suitable solution, with a relative closeness of 0.640. Radulescu et al.(2024) described different methods for calculating the relative closeness coefficient in the TOPSIS method for ranking IoT [20]. Sathiyamurthi et al.(2024) proposed AHP-TOPSIS and geospatial techniques for the assessment of crop suitability analysis in a case study of the Krishnagiri district of India [25]. Wang et al. (2024) used an entropy-based TOPSIS model to dynamically evaluate green development in agriculture and rural areas [29]. Kadlag (2024) used the AHP method to select fertilizers [8]. Yiow et al.(2025) used AHP and TOPSIS methods to select natural fiber composite materials for two-stroke marine engines [27]. The author used four criteria (Tensile Strength, Young's modulus, and price) for the selection of the natural fibers and biopolymers. Referred literature indicates that several MCDM methods have been used to solve problems in various areas. In the current study, no related work was reported on the ranking of fertilizers using the TOPSIS approach. Therefore, efforts have been made to rank inorganic and organic fertilizers using the TOPSIS method.

1.2 Contribution of the present study

This paper presents the following contributions:

1. The TOPSIS method was successfully applied to the village of Nimgaon Bhojapur (latitude 19.62158, longitude 74.13609) in Tehsil Sangamner, Ahilyanagar District, Maharashtra, India.
2. Two alternatives (inorganic and organic) and six criteria: fertilizer availability (FA), fertilizer cost (FC), yield (Y), fertilizer impact on human health (FH), soil (FS), and environment (FE). Organic fertilizers rank first with a relative closeness value of 0.674088.
3. The application of TOPSIS to select the most suitable fertilizer is a novel approach for agricultural planning and management.

2.0 MATERIAL AND METHODS

As mentioned in the previous section, MCDM methods have diverse applications in various fields. MCDM methods are classified into MADM and MODM methods, which are further classified into MAVT, MAUT, SAW, AHP, ANP, TOPSIS, ELCTRE, and PROMETHEE methods, which are classified into mathematical model applications such as LP, NLP, GP, and CP. Each method has applications in various fields such as structural applications, transportation, logistics, agriculture, industry, finance, business, chemical engineering, energy management, and irrigation. Hwang and Yoon 1981 used a diverse range of applications. The TOPSIS method selects the most suitable alternative: the minimal distance to the optimal solution and the greatest distance from the least favourable solution. An optimal solution enhances the benefit criteria while reducing the cost criteria. Conversely, a least favourable solution increases the cost criteria and decreases the benefit criteria. A three stage hierarchy model was developed, including objective, alternative, and criteria selections.

2.1 Study Area:

A methodology using the TOPSIS approach was successfully applied to farmers in Nimgaon Bhojapur village (latitude 19.62158, longitude 74.13609), Maharashtra State, India (Figure 1). Data were collected from farmers and stakeholders based on their past agricultural experiences.

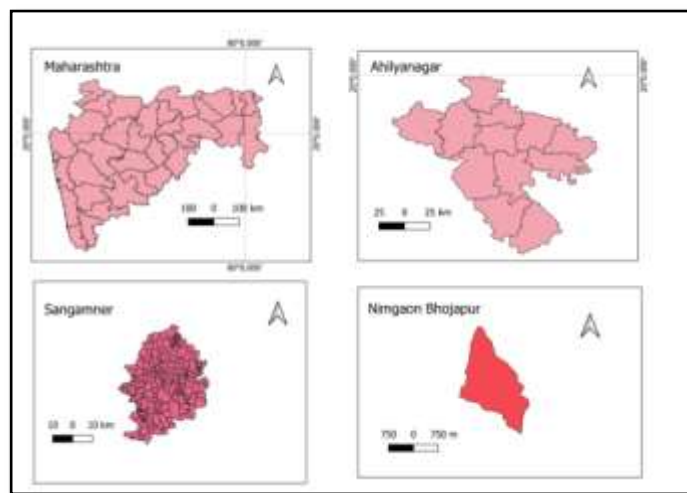


Figure 1: Map of Nimgaon Bhojapur Village (19.62158,74.13609)

2.2 Steps to use in TOPSIS method

- Define the problem: Objective/Problem, Criteria and Alternatives are identified.
- Creating a decision matrix: A Pairwise decision matrix is formed. Weights were assigned to each criterion based on their relative importance.
- Normalize the decision matrix: the decision matrix to convert all criteria into the same unit of measurement. This is done by dividing each value in a column by the sum of all the values in that column.

$$R_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^m X^2_{ij}}}$$

where $\sum_{i=1}^m X^2_{ij}$ is summation of the square of the values of the column for each alternative and different criterion.

- Determine the optimal and least favorable ideal solutions: The optimal ideal solution is the alternative that has the highest score on all criteria, whereas the negative ideal solution is the alternative that has the lowest score on all criteria.

$$D^+ = (v_1^+, v_2^+, \dots, v_j^+)$$

$$D^- = (v_1^-, v_2^-, \dots, v_j^-)$$

Where $v_j^+ = \text{Max } v_{ji}$, if j is the benefit attribute.

= Min v_{ji} if j is a cost attribute.

\bar{v}_j = Min v_{ji} , if j is the benefit attribute.

= Max v_{ji} if j is a cost attribute.

e. Calculate the distance to the optimal and least favorable ideal solutions: Calculate the shortest distance of each alternative from the positive and negative ideal solutions.

$$S_i^+ = \sqrt{\sum_{j=1}^j (v_{ij} - v_j^+)^2}$$

$$S_i^- = \sqrt{\sum_{j=1}^j (v_{ij} - v_j^-)^2}$$

f. Determine the relative closeness to the ideal solution: calculate the relative closeness of all alternatives to the ideal solution by dividing the distance to the least favorable ideal solution by the sum of the distances to the ideal optimal and ideal least favorable solutions.

$$V_i = \frac{S_i^-}{S_i^+ + S_i^-}$$

g. Rank the alternatives: Rank the alternatives based on their relative closeness to the ideal solution. The alternative with the highest relative closeness is the best option. The TOPSIS method provides a systematic and objective approach to decision making, but it requires careful consideration of the criteria and weights assigned to them.

3 RESULT AND DISCUSSION

The TOPSIS methodology was successfully applied to a group of farmers, and the following results were obtained for ranking the fertilizers:

a) Prepare the Pairwise Decision Matrix

The eigenvalues and eigenvectors were calculated from a pairwise comparison matrix (Table 1) based on data collected from field experts.

Table 1: Pairwise Comparison Matrix

Sr. No	Criteria	FA	FC	Y	FS	FE	FH
1	FA	1	0.5	0.33	0.5	0.33	0.33
2	FC	2	1	0.5	0.33	0.33	0.33
3	Y	3	2	1	3	3	0.5
4	FS	2	3	0.33	1	0.5	0.5
5	FE	3	3	0.33	2	1	1
6	FH	3	3	2	2	1	1

(FA: Fertilizer availability; FC: Fertilizer cost; Y: Yield, FS: Fertilizer effect on Soil, FE: Fertilizer effect on the Environment, FH: Fertilizer effect on human health).

b) Check for Consistency Ration (CR)

After preparing the pairwise matrix, the relative weights of the criteria, lambda, the consistency index of the matrix, and the consistency ratio were calculated. The CR normalization method was used in the calculations. The criteria were ranked according to their weights.

The highest eigenvalue calculated from the pairwise comparison matrix (table 1) was $\lambda_{max} = 6.42398$.

$$\text{Consistency Index (CI)} = \frac{\lambda_{max} - N}{N - 1} = \frac{6.42398 - 6}{6 - 1} = 0.084796$$

Where N= Number of criteria

Random Index (RI) value for 6x6 matrix = 1.24

$$\text{Consistency Ratio (CR)} = \frac{CI}{RI} = \frac{0.084796}{1.24} = 0.068384$$

The obtained CR value was less than 0.1, indicating an appropriate assessment of the criteria weights and pairwise decision matrix. Table 2 presents the individual rankings of criteria according to their relative weights.

Table 2: Ranking of the available criteria

Sr. No	Criteria	Relative Weights	Rank
1	Fertilizer impact on Human Health	0.260297	1
2	Yield	0.260063	2
3	Fertilizer impact on Environment	0.198307	3
4	Fertilizer impact on Soil	0.131231	4
5	Fertilizer Cost	0.085887	5
6	Fertilizer Availability	0.064214	6

The calculated criteria weights were assigned to alternatives to convert the decision matrix into the same unit of measurement. Table 3 lists the assigned weights for each criterion.

Table 3: Weights are assign to alternatives based on relative importance of criteria

Sr. No.	Fertilizer	FA	FC	Y	FS	FE	FH
	Weights	0.064214289	0.085887279	0.26006312	0.131230823	0.198307441	0.260297048
1	Organic	4	6	5	8	8	7
2	Inorganic	7	7	7	3	5	4

$$R_{ij} = \frac{X_{ij}}{\sqrt{\sum_{i=1}^m X^2_{ij}}}$$

where $\sum_{i=1}^m X^2_{ij}$ is the summation of the square of the values of the column for each alternative and different criterion.

Sample calculation: X^2

$$\frac{4}{\sqrt{4^2 + 7^2}} = 0.496138938$$

$$\frac{7}{\sqrt{4^2 + 7^2}} = 0.868243142$$

Decision matrix is converted into same unit of measurement in Table 4.

Table 4: Decision matrix converted into the same unit of measurement

Sr. No.	Fertilizer	FA	FC	Y	FS	FE	FH
	Weights	0.064214289	0.085887279	0.26006312	0.131230823	0.198307441	0.260297048
1	Organic Fertilizer	0.496138938	0.650791373	0.581238194	0.936329178	0.847998304	0.868243142
2	Inorganic Fertilizer	0.868243142	0.759256602	0.813733471	0.351123442	0.585205736	0.496138938

$$\frac{4}{\sqrt{4^2 + 7^2}} = 0.496138938$$

$$\frac{7}{\sqrt{4^2 + 7^2}} = 0.868243142$$

Normalized values were used to prepare a weighted normalization decision matrix. Table 5 presents the weighted normalization decision matrix.

Table 5: Weighted normalization decision matrix

Sr. No.	Fertilizer	FA	FC	Y	FS	FE	FH
	Weights	0.064214289	0.085887279	0.26006312	0.131230823	0.198307441	0.260297048
1	Organic Fertilizer	0.031859209	0.0558947	0.151158618	0.122875249	0.168164374	0.226001126
2	Inorganic	0.055753616	0.065210484	0.211622066	0.046078218	0.116050652	0.129143501

Fertilizer

Weight x Normalised value = Normalised Weight

0.064214289 x 0.496138938=0.031859209

Weight x Normalised value = Normalised Weight

0.064214289 x 0.868243142=0.055753616

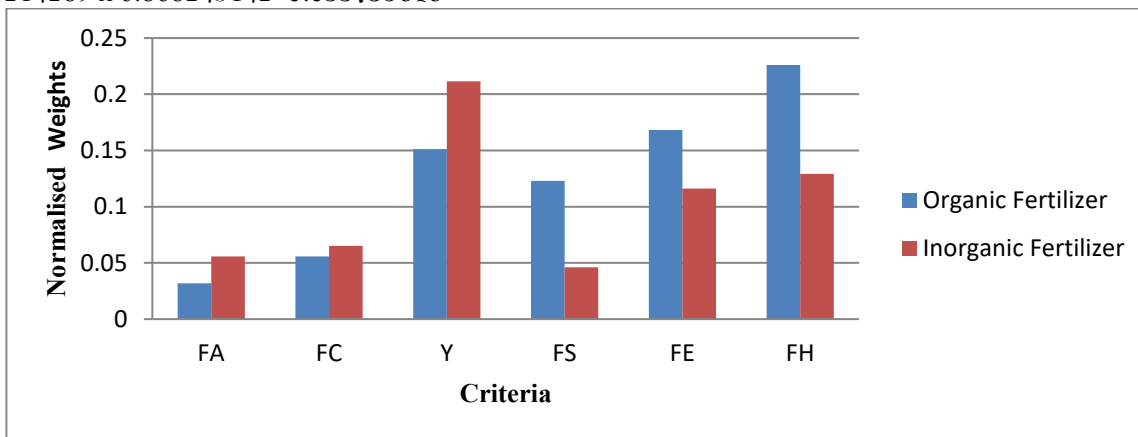


Figure 2: Criteria and normalised weights representation

Figure 2 shows that inorganic fertilizers are more readily available than are organic fertilizers. The cost of the time yield from inorganic fertilizers is found to be high. Organic fertilizers have no or few adverse effects on the soil, environment, and environment.

c) Determine the optimal and least favorable ideal solution

In the mentioned work group, benefit criteria were considered for positive assessment and cost groups were considered for negative assessment, as shown in Table 6.

inorganic fertilizers is higher than that of organic fertilizers; in short,

Table 6: Benefit and cost identification

Sr. No	Benefit	Positive	Maximum Value
1.	Cost	Negative	Minimum Value

$$D^+ = (v_1^*, v_2^*, \dots, v_j^*)$$

Where $v_j^* = \text{Max } v_{ji}$ if j is benefit attribute

= $\text{Min } v_{ji}$ if j is a cost attribute.

Value closed to positive ideal solution are workout in Table 7.

Table 7: Positive Ideal Solution

Sr. No	FA	FC	Y	FS	FE	FH
1	0.055753616	0.0558947	0.211622066	0.122875249	0.168164374	0.226001126
2	0.055753616	0.0558947	0.211622066	0.122875249	0.168164374	0.226001126
	Maximum	Minimum	Maximum	Maximum	Maximum	Maximum

$$D^- = (v_1, v_2, \dots, v_j)$$

Where $v_j = \text{Min } v_{ji}$ if j is benefit attribute

= $\text{Max } v_{ji}$ if j is a cost attribute

Value farthest end from optimal ideal solution are workout in Table 8.

Table 8: Negative Ideal Solution

Sr. No	FA	FC	Y	FS	FE	FH
1	0.031859209	0.065210484	0.151158618	0.046078218	0.116050652	0.129143501
2	0.031859209	0.065210484	0.151158618	0.046078218	0.116050652	0.129143501
	Minimum	Maximum	Minimum	Minimum	Minimum	Minimum

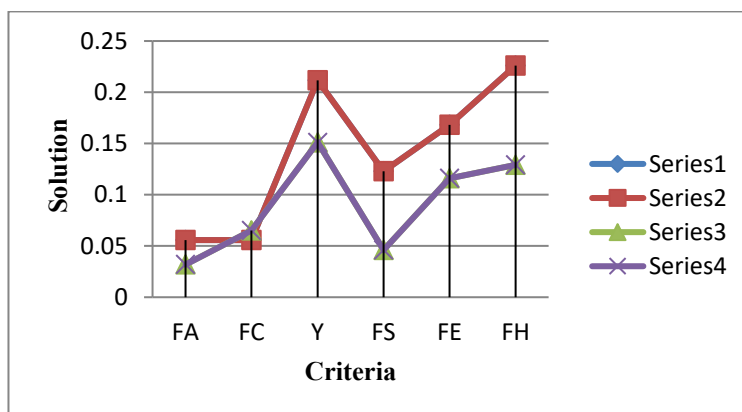


Figure 3: Positive and negative ideal solution

Series 1, 2, 3 and 4 in figure 3 respectively represents the optimal and least favourable ideal solution for Organic and Inorganic fertiliser.

d) Determine the optimal ideal and least favorable ideal separation

The optimal and least favorable ideal separation values were calculated for the final rankings in Table 9 and 10, respectively.

Table 9: Optimal Ideal Separation S+ ve

Sr. No	FA	FC	Y	FS	FE	FH	Sum
1	0.000570943	0	0.003655828	0	0	0	0.065014
2	0	8.67838 x 10 ⁻⁰⁵	0	0.005897784	0.00271584	0.0093814	0.134469

Table 10: Least Favourable Ideal Separation S-ve

Sr. No	FA	FC	Y	FS	FE	FH	Sum
1	0	8.67838 x 10 ⁻⁰⁵	0	0.005897784	0.00271584	0.0093814	0.134469
2	0.000570943	0	0.003655828	0	0	0	0.065014

e) Determine the relative closeness to the ideal solution:

The TOPSIS method picks the most appropriate alternative: the shortest distance from the optimal ideal solution and the farthest distance from the least favourable ideal solution.

$$V_i = \frac{S_i^-}{S_i^+ + S_i^-} = \frac{0.134469}{0.134469 + 0.065014} = 0.674088$$

$$\frac{0.065014}{0.065014 + 0.134469} = 0.325912$$

f) Finalization of Rank

Based on the relative closeness final rank of alternatives were finalised in Table 11.

Table 11: Ranking of alternatives based on TOPSIS approach

Sr. No	Alternative	Relative Closeness Value	Rank
1	Organic	0.674088	1
2	Inorganic	0.325912	2

These results indicate that organic fertilizers perform better than inorganic fertilizers do. In the current practice, some farmers use inorganic fertilizers on their farms only to obtain the maximum yield (table 4). Farmers/stakeholders were aware that there would be no adverse impact of organic fertilizers on soil, human health, or the environment. Figure 4 represents the organic fertilizer secure rank first, with a relative closeness value of 0.674088.

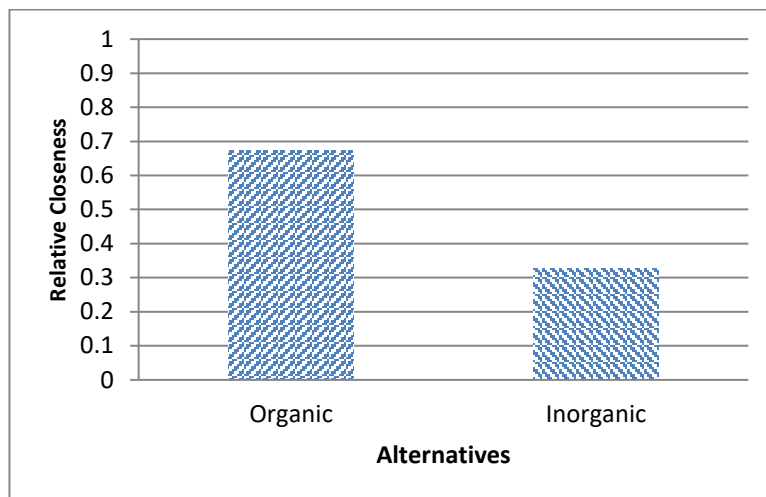


Figure 4: Ranking of inorganic and organic fertilizer based on TOPSIS approach

4 CONCLUSION:

This study presents an approach to the TOPSIS method for farmers in Maharashtra. Based on the results, the following conclusions can be drawn.

1. It is difficult to make judicial decisions if many alternatives and criteria are involved in the decision-making process. In the present study, two alternatives (Inorganic and Organic fertilizers) and six criteria (fertilizer availability (FA), fertilizer cost (FC), yield (Y), fertilizer impact on human health (FH), soil (FS), and environment (FE)) were used to rank fertilizers.
2. According to the TOPSIS results, organic fertilizers obtained rank 1, with a relative closeness value of 0.674088, against inorganic fertilizers with a value of 0.325912.(Table 11)
3. The results showed that organic fertilizers could improve soil fertility, water-holding capacity, and nutrient accumulation. Furthermore, the excessive use of inorganic fertilizers has adverse effects on soil and human health. And on the environment.
4. The proposed methodology will be helpful to new researchers in the field of irrigation planning.

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Conflict of Interest: The authors declare no conflicts of interest.

Ethical Compliance: All techniques performed in this study involving human contributors were in accord with the ethical standards of the institution.

Data Assess Statement: Research data supporting this publication are available with the author.

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