Available online at http://scik.org
Commun. Math. Biol. Neurosci. 2021, 2021:92
https://doi.org/10.28919/cmbn/6930
ISSN: 2052-2541

INTEGRATION INTERVAL TYPE-2 FAHP-FTOPSIS GROUP DECISION-MAKING PROBLEMS FOR SALT FARMER RECOMMENDATION

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Abstract: The Covid-19 pandemic has caused the development of the marine economy, especially the salt business of Madurese Indonesian people, to experience a decline. Some government programs are marketplace training, providing people's credit assistance, providing appropriate technical assistance such as geomembranes, and online marketing. There are difficulties in running and implementing government programs, so a decision-making system is needed for mapping salt farmers. The purpose is construct a multi-criteria group decision-making model by performing a hybrid interval type 2 FAHP and FTOPSIS method for mapping salt farmers with interval Triangular Fuzzy Number (TFN). The contribution is to determine recommendations based on TFN with the same middle point and group support system. Interval type-2 FAHP is used to determine the most influential indicator on salt farmer mapping, Interval type-2 TOPSIS is used to determine salt farmer recommendations. Fuzzy type-2 provides more accurate modeling, better rating value performance, and high flexibility. The findings of this study are indicators that most influence

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Received October 26, 2021

recommendation of salt farmers are marketing models, production yields, and profit. The results of the recommendations stated that 45% received good recommendations, 35% entered into moderate recommendations and 20 % entered into bad recommendations.

Keywords: interval type-2; FAHP; FTOPSIS; salt farmer; recommendation.

2010 AMS Subject Classification: 91B06.

1. INTRODUCTION

Indonesia's position as an archipelagic country with a very wide sea causes each region to have the potential to produce salt. The largest salt-producing island in Indonesia is Madura. Based on statistical data from the Ministry of Marine Affairs and Fisheries in 2018, Sampang Madura became the largest salt-producing district in Indonesia with a total production of 312,061 tons [1]. The Covid-19 pandemic has caused all sectors to be paralyzed, including salt farmers in Sampang Madura. The government has also made new policies regarding Large-Scale Social Restrictions, physical distancing and is currently entering the new normal [2].

This policy affects the market share in the sale and production of salt in Sampang Madura. Various government program efforts (Marine and Fisheries Service) in helping salt farmers face the acceleration of handling Covid-19, namely through technology training programs, providing People's business credit assistance, providing appropriate technical assistance such as geomembranes to increase the amount of production and online marketing training [3]. The problem with this research is that many salt farmers have experienced a decrease in salt production and have difficulty selling salt products due to the impact of the Covid-19 pandemic, so a mapping model for salt farmers is needed to help run the office's work program during the Covid-19 pandemic and the 4.0 industrial revolution.

This mapping model is guided by several indicators, namely land area, production output, number of workers, ownership, operating profit, marketing system, market place. Some indicators contain information that is not clear, contains uncertainty and inaccuracies in the data, thus requiring appropriate decision-making methods. The purpose is to construct a hybrid interval type

2 fuzzy AHP, TOPSIS method for mapping salt farmers. Fuzzy type-2 provides more accurate modeling, better rating value performance, and high flexibility [4][5][6][7].

Linguistic modeling interval type-2 fuzzy is clear and has preferred accuracy than fuzzy type-1 [8]. Determine entropy weight, AHP method has advantage of solving problem of many complex criteria into a hierarchical structure to get a suitable and easy-to-understand model [9][10][11]. In testing expert or respondent judgments and optimizing multi-criteria decisions, the AHP method has advantages in testing the consistency of criteria assessment results [12][13][14][15]. The use of the consistency index has also been used in several previous studies on multi-criteria-based decisions to measure the performance of SMEs [15] [16][17].

In determining selection and recommendation of salt farmers, TOPSIS method is capable and suitable for multicriteria decision-making based on the Euclidian distance method. TOPSIS has a calculation concept that is simple, easy to understand, and computationally efficient [18][19]. AHP and TOPSIS methods have been widely used in solving decision-making problems. Several studies have used a hybrid method of AHP and TOPSIS to evaluate and select software quality [18][20][21]. Several studies have used a hybrid method of AHP and TOPSIS to evaluate and select software quality [6] [21][22]. Several journals use the fuzzy method to handle data that contains uncertainty and inaccuracies, fuzzy method is also hybridized with AHP, ANP, and TOPSIS for weighting and data selection [23][24][14][4]. This research uses a hybrid Fuzzy multi-criteria method and an optimization model using Mathematical Optimization Programming (MOP). FAHP was used for weighting allocation water, Fuzzy TOPSIS method was used to determine the best performance of various water resources [25].

Based on previous research, there has been no research on salt mapping using the interval fuzzy type-2 method, the indicators used are also different because they are adjusted to conditions and needs of the Sampang Madura area. The contribution of this research is mapping salt farmers using a decision-making model based on group by optimizing decisions based on a modification of the Triangular Fuzzy Number (TFN) interval point. The decisions made based on group decision-making have a higher consensus than individual decisions [10][26]. Therefore, this study uses an integration of fuzzy type-2 AHP, TOPSIS method to determine the most influential indicators and recommendations for improvement salt farmer facing the Covid-19 pandemic.

2. PRELIMINARIES

2.1. Interval type-2 Fuzzy Sets

The fuzzy theory was first conveyed by Zadeh (1975). Fuzzy Interval Type 2 is an extension of fuzzy type-1. Fuzzy theory is also called fuzzy type-1, this theory can handle the problem of uncertainty in the data by having membership functions and linguistic variables. When compared to fuzzy type-1, interval type-2 fuzzy provides more accurate modeling, better rating value performance, and high flexibility. type-2 fuzzy is suitable for MCDM-based decision-making problems for real problems, can handle more judgments for data that has uncertainty and subjectivity. Type-2 fuzzy is widely applied in the real world because it contains computational stages that are easier to implement. Interval type-2 Fuzzy Sets $\tilde{\tilde{A}}$ in the universe of discourse X as follows:

$$\tilde{\tilde{A}} = \{((x,u), \mu_{\tilde{\tilde{A}}}(x,u)) \mid \forall x \in X, \forall u \in J_X \subseteq [0,1], 0 \le \mu_{\tilde{\tilde{A}}}(x,\mu) \le 1\}$$

With $\mu_{\tilde{\tilde{A}}}$ = membership of function

J_X = interval in [0,1]

Interval type-2 Fuzzy Sets $\tilde{\tilde{A}}$ can represented as follows:

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

With $J_X \subseteq [0,1]$, and $\iint$ state union overall acceptable *x* and *u*

Interval type-2 Fuzzy Sets $\tilde{\tilde{A}}$ can be regarded as case of fuzzy type-2 as follows:

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

With $J_X \subseteq [0,1]$,

2.2. Membership Function Triangular Fuzzy Number (TFN)

The fuzzy membership is a mapping of interval data input as membership input. This function approach uses an interval triangular curve or called Interval Value Triangular Fuzzy type-2 as shown in Figure 1.

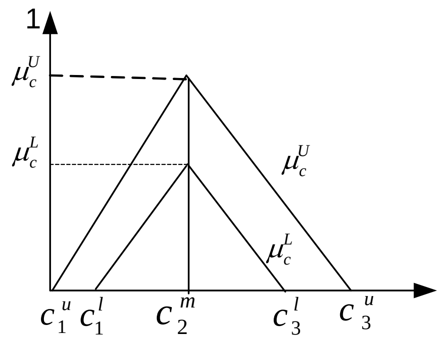

Figure 1. Interval type-2 Triangular Fuzzy Number [19]

According to Fuh, C.F., et al. [27], membership function interval type-2 triangular Fuzzy number is defined as follows:

$$\mu_c^L(x) = \begin{cases} (x - c_1^l)/(c_2^m - c_1^l); & c_1^l \le x \le c_2^m \\ (c_3^l - x)/(c_3^l - c_2^m); & c_2^m \le x \le c_3^l \\ 0; & otherwise, \end{cases} \tag{1}$$

With $C^L = (c_1^l, c_2^m, c_3^l), c_1^l \le c_2^m \le c_3^l.$

$$\mu_c^U(x) = \begin{cases} (x - c_1^u)/(c_2^m - c_1^u); & c_1^u \le x \le c_2^m \\ (c_3^u - x)/(c_3^u - c_2^m); & c_2^m \le x \le c_3^u \\ 0; & otherwise, \end{cases} \tag{2}$$

With $C^U = (c_1^u, c_2^m, c_3^u), c_1^u \le c_2^m \le c_3^u.$

Arithmetic operations for TFN interval numbers with the same middle point can be seen from the following equation [19]:

$$C = [(c_1^u, c_1^l, c_2^m, c_3^l, c_3^u)]$$

With $c_1^u \le c_1^l \le c_2^m \le c_3^l \le c_3^u$

$$K = [(k_1^u, k_1^l, k_2^m, k_3^l, k_3^u)]$$

With $k_1^u \le k_1^l \le k_2^m \le k_3^l \le k_3^u$

The arithmetic operations of Interval Triangular Fuzzy Number (TFN) are:

1. The addition operation of different *Interval TFN C, K:*

$$\begin{aligned} C \oplus K &= [(c_1^u, c_1^l, c_2^m, c_3^l, c_3^u)] \oplus [(k_1^u, k_1^l, k_2^m, k_3^l, k_3^u)] \\ &= [(c_1^u + k_1^u, c_1^l + k_1^l, c_2^m + k_2^m, c_3^l + k_3^l, c_3^u + k_3^u)] \end{aligned} \tag{3}$$

2. The Subtraction operation of different *Interval TFN C, K:*

$$C - K = [(c_1^u, c_1^l, c_2^m, c_3^l, c_3^u)] - [(k_1^u, k_1^l, k_2^m, k_3^l, k_3^u)]$$
$$= [(c_1^u - k_3^u,\ c_1^l - k_3^l,\ c_2^m - k_2^m,\ c_3^l - k_1^l, c_3^u - k_1^u)] \quad (4)$$

3. The addition operation of different *Interval TFN C, K:*

$$C \otimes K = [(c_1^u, c_1^l, c_2^m, c_3^l, c_3^u)] \otimes [(k_1^u, k_1^l, k_2^m, k_3^l, k_3^u)]$$
$$= [(c_1^u k_1^u,\ c_1^l k_1^l, c_2^m k_2^m, c_3^l k_3^l,\ c_3^u k_3^u)] \quad (5)$$

4. The multiplication operation of different *Interval TFN C, K:*

$$\frac{C}{K} = \frac{[(c_1^u, c_1^l, c_2^m, c_3^l, c_3^u)]}{[(k_1^u, k_1^l, k_2^m, k_3^l, k_3^u)]}$$
$$= [(\frac{c_1^u}{k_3^u}, \frac{c_1^l}{k_3^l}, \frac{c_2^m}{k_2^m}, \frac{c_3^l}{k_1^l}, \frac{c_3^u}{k_1^u})] \quad (6)$$

5. The multiplication operation of different *Interval TFN C* dan *constant number* $\lambda\,(\lambda > 0)$:

$$\lambda.\ K = \lambda.[(c_1^u, c_1^l, c_2^m, c_3^l, c_3^u)]$$
$$= [(\lambda.c_1^u, \lambda.c_1^l, \lambda.c_2^m, \lambda.c_3^l, \lambda.c_3^u)]$$

2.3. Hybrid methodology Fuzzy Interval type-2 AHP and TOPSIS

The methodology of this research can be seen in Figure 3. Hybrid interval fuzzy type-2 AHP and TOPSIS. This method step begins with determining the salt mapping indicator first. Salt mapping indicators are determined based on several criteria, namely land area, number of workers, capital, production results, operating profit, marketing system. Then determine the fuzzy type-2 interval scale, determine the pairwise comparison matrix, calculate the geometric means and get the criteria weights. After the FAHP type-2 process is complete, the process continues with the FTOPSIS type-2 method. This method begins by determining the fuzzy type-2 interval rating scale to determine the data for each indicator. Determine the alternative value of each salt farmer data, weighted normalization by entering weights based on data from the FAHP method weights. Determining the value of defuzzification of weights, determining positive and negative ideal values, normalization, recommendations, and mapping of salt farmers.

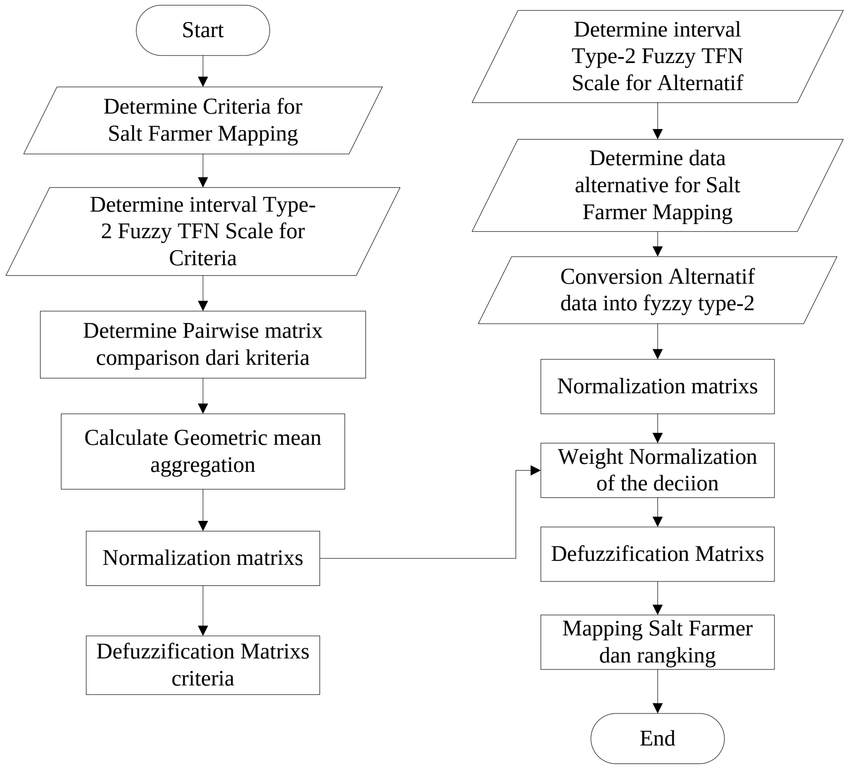

Figure 2. Hybrid interval type-2 fuzzy AHP dan TOPSIS

3. Main Results

3.1. Hybrid type-2 FAHP dan type-2 FTOPSIS Model with TFN function.

Hybrid construction of interval type-2 FAHP and FTOPSIS methods with same and different middle points in the AHP Triangular Fuzzy Number (TFN) model [28][29][30]. This construction is based on Figures 3 and 4. The steps for the hybrid method of IVFAHP and IVFTOPSIS are

1. Construction of matrix C, which is a matrix comparison between criteria in mapping salt farmers

$$C = \begin{bmatrix} 1 & c_{12} & c_{13} & \cdots & c_{1n} \\ c_{21} & 1 & c_{23} & \cdots & c_{2n} \\ c_{31} & c_{32} & 1 & \cdots & c_{3n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ c_{n1} & c_{n2} & c_{n3} & \cdots & 1 \end{bmatrix} \quad (7)$$

With i, j = 1, 2, ..., n.

C = Pairwise comparison matrix, c_{ij} = Matrix elements C row to i column to j

2. Conversion of matrix C into an interval matrix of type-2 triangular fuzzy number as shown in Figure 3. Using the same middle point, while Figure 4. interval type-2 with a different middle point.

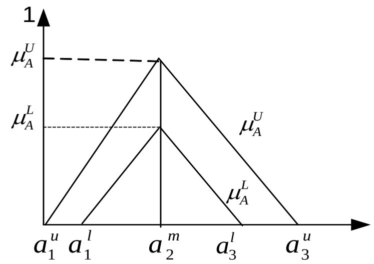

Figure 3. Interval type-2 with the same middle point

Matrix A can be written based on Figure 3. as follows

$$A = \begin{bmatrix} 1 & a_{12} & a_{13} & \cdots & a_{1n} \\ a_{21} & 1 & a_{23} & \cdots & a_{2n} \\ a_{31} & a_{32} & 1 & \cdots & a_{3n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & a_{n3} & \cdots & 1 \end{bmatrix} \tag{8}$$

$$a_{ij} = (a^u_{1ij}, a^l_{1ij}, a^m_{2ij}, a^l_{3ij}, a^u_{3ij}),\ a^{-1}_{ij} = \left(\frac{1}{a^u_{3ij}}, \frac{1}{a^l_{3ij}}, \frac{1}{a^m_{2ij}}, \frac{1}{a^l_{1ij}}, \frac{1}{a^u_{1ij}}\right),$$

A = Pairwise comparison matrix, μ^l_A = Membership degree of Lower limit, μ^u_A = Membership degree of upper limit, a_{ij} = Criteria interval row to i column to j, a^{-1}_{ij} = Criteria Reciprocal row to i column to j, a^u_{1ij} = upper point 1, a^l_{1ij} = lower point 1, a^m_{2ij} = middle point 2, a^l_{3ij} = Lower point 3 , a^u_{3ij} = upper point 3.

The decision-making model in interval TFN with different middle points where ml > mu point is shown in Figure 4.

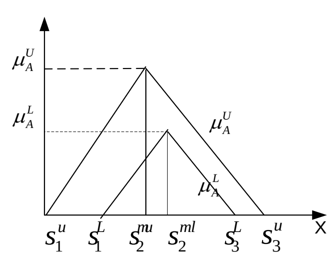

Figure 4. Interval type-2 with different middle point

Matrix S can be written based on Figure 2. as follows

$$
: S = \begin{bmatrix} 1 & s_{12} & s_{13} & \dots & s_{1n} \\ s_{21} & 1 & s_{23} & \dots & s_{2n} \\ s_{31} & s_{32} & 1 & \dots & s_{3n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ s_{n1} & s_{n2} & s_{n3} & \dots & 1 \end{bmatrix} \tag{9}
$$

With

$$
s_{ij} = (s^u_{1ij}, s^l_{1ij}, s^{mu}_{2ij}, s^{ml}_{2ij}, s^l_{3ij}, s^u_{3ij}),\ \ s^{-1}_{ij} = (\frac{1}{s^u_{3ij}}, \frac{1}{s^l_{3ij}}, \frac{1}{s^{mu}_{2ij}}, \frac{1}{s^{ml}_{2ij}}, \frac{1}{s^l_{1ij}}, \frac{1}{s^u_{1ij}}),
$$

S = Pairwise comparison matrix; μ^l_A = Membership degree of Lower limit; μ^u_A = Membership degree of upper limit; s_{ij} = Criteria interval row to i column to j; s^{-1}_{ij} = Reciprocal criteria row to i column to j; s^u_{1ij} = upper point 1; s^l_{1ij} = lower point 1; s^m_{2ij} = middle point 2; s^l_{3ij} = middle point 3; , s^l_{3ij} = lower point 3 , s^u_{3ij} = upper point 3. .

3. According to Step 2, the matrix is converted to an interval scale. Assessment of several respondents in groups using Interval Geometric Means Aggregation (IGMA) method. Matrix V is an IGMA calculation matrix that can be expressed as follows:

$$
V = \begin{bmatrix} v_{11} & v_{12} & v_{13} & \dots & v_{1n} \\ v_{21} & v_{22} & v_{23} & \dots & v_{2n} \\ v_{31} & v_{32} & v_{33} & \dots & v_{3n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ v_{n1} & v_{n2} & v_{n3} & \dots & v_{nn} \end{bmatrix} \tag{10}
$$

$$
v_{ij} = \left(\left(\prod_{k=1}^{n} a^u_{1ijk} \right)^{1/n}, \left(\prod_{k=1}^{n} a^l_{1ijk} \right)^{1/n}, \left(\prod_{k=1}^{n} a^m_{2ijk} \right)^{1/n}, \left(\prod_{k=1}^{n} a^l_{3ijk} \right)^{1/n}, \left(\prod_{k=1}^{n} a^u_{3ijk} \right)^{1/n} \right)
$$

With i, j = 1,2, ..., n.

V = Geometric Mean Aggregation, v_{ij} = Elements of matrix V in row i, column j, k = Respondents, n = Number of experts.

4. Calculate weight criteria of matrix V same middle point. The weight criteria matrix V is denoted by N^*. The weight of criteria for triangular fuzzy number can be expressed as follows:

$$\mathrm{N}^* = \begin{bmatrix} n_1 \\ n_2 \\ n_3 \\ \vdots \\ n_n \end{bmatrix}, \tag{11}$$

$$n_i = \left(\frac{\prod_{j=1}^{n} (v_{1ij}^{u})^{1/n}}{\sum_{i=1}^{n} v_{3ij}^{u}}, \frac{\prod_{j=1}^{n} (v_{1ij}^{l})^{1/n}}{\sum_{i=1}^{n} v_{3ij}^{l}}, \frac{\prod_{j=1}^{n} (v_{2ij}^{m})^{1/n}}{\sum_{i=1}^{n} v_{2ij}^{m}} \frac{\prod_{j=1}^{n} (v_{3ij}^{l})^{1/n}}{\sum_{i=1}^{n} v_{1ij}^{l}}, \frac{\prod_{j=1}^{n} (v_{3ij}^{u})^{1/n}}{\sum_{i=1}^{n} v_{1ij}^{u}} \right)$$

With *i, j = 1,2, ..., n.*

$\tilde{\tilde{\mathrm{N}}}$ = Criteria weighting matrix, n_i = Criteria weighting in interval, n = Number of criteria, v_{1ij}^{u} = upper point 1, v_{1ij}^{l} = lower point 1 , v_{2ij}^{m} = middle point 2 ; v_{3ij}^{l} = lower point 3 , v_{3ij}^{u} = upper point 3

5. Calculate defuzzification of u_i

   Defuzzification is to change fuzzy output into crisp values using the best non-interval fuzzy performance (BNIP) method. BNIP can be stated as follows

$$BNIP_i = \frac{\alpha_1 \left[\frac{(u_{3i}^{u} - u_{1i}^{u}) + (\mathrm{u}_{2i}^{mu} - u_{1i}^{u})}{3} + u_{1i}^{u} \right] + \alpha_2 \left[\frac{(u_{3i}^{l} - u_{1i}^{l}) + (\mathrm{u}_{2i}^{ml} - u_{1i}^{l})}{3} + u_{1i}^{l} \right]}{2}, \tag{12}$$

   With i = 1,2, ..., n.

6. Construction of K Matrix.

   This is the interval type-2 FTOPSIS method step, while steps 1 to 5 are interval type-2 FAHP method. This step refers to number 2 based on the Interval Triangular Fuzzy Number model, alternative decision matrix against criteria denoted by K can be stated as follows:

$$\mathrm{K} = \begin{bmatrix} k_{11} & k_{12} & \dots & k_{1n} \\ k_{21} & k_{22} & \dots & k_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ k_{n1} & k_{n2} & \dots & k_{nn} \end{bmatrix} \tag{13}$$

   With $k_{ij} = (k_{1ij}^{u}, k_{1ij}^{l}, k_{2ij}^{m}, k_{3ij}^{l}, k_{3ij}^{u}),$ i = 1, 2, 3, ..., n, and j = 1, 2, 3, …, n.

K = Alternative decision matrix against the criteria, k_{ij} = weight of the criteria, k^u_{1ij} = upper point 1, k^l_{1ij} = lower point 1 , k^m_{2ij} = middle point2 , k^l_{3ij} = lower point3 , k^u_{3ij} = upper point 3.

7. Construct a normalized decision matrix denoted by B can follows: calculate the normalized matrix expressed by B as follows:

$$B = \begin{bmatrix} b_{11} & b_{12} & \dots & b_{1n} \\ b_{21} & b_{22} & \dots & b_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ b_{n1} & b_{n2} & \dots & b_{nn} \end{bmatrix} \tag{14}$$

With

$$b_{ij} = \left[\frac{k^u_{1ij}}{c^+_j}, \frac{k^l_{1ij}}{c^+_j}, \frac{k^m_{2ij}}{c^+_j}, \frac{k^l_{3ij}}{c^+_j}, \frac{k^u_{3ij}}{c^+_j} \right], \text{ j = 1, 2, 3,...,n.}$$

$$b_{ij} = \left[\frac{a^-_j}{k^u_{3ij}}, \frac{a^-_j}{k^l_{3ij}}, \frac{a^-_j}{k^m_{2ij}}, \frac{a^-_j}{k^l_{1ij}}, \frac{a^-_j}{k^u_{1ij}} \right], \text{ j = 1, 2, 3,...,n.}$$

$c^+_j = \max(h_{1j}, h_{2j}, \dots, h_{nj})$, $a^-_j = \min(h_{1j}, h_{2j}, \dots, h_{nj})$, $j = 1, 2, 3, \dots, n$,.

B = Normalized decision matrix, b_{ij} = Elements of the matrix B for alternative i criteria j,

k^u_{3ij} = Upper point 3 , k^l_{3ij} = Lower point 3, k^m_{2ij} = Middle Point 2, k^l_{1ij} = lower point 1,

k^u_{1ij} = upper point 1

8. Construct of a weighted normalized decision matrix denoted by D can be expressed as follows:

$$\text{D} = \begin{bmatrix} d_{11} & d_{12} & \dots & d_{1n} \\ d_{21} & d_{22} & \dots & d_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ d_{n1} & d_{n2} & \dots & d_{nn} \end{bmatrix} \tag{15}$$

Weighted normalization decision matrix based on step number 4

$$d_{ij} = \tilde{w}_j . b_{ij}$$

$$d_{ij} = (b^u_{1ij}.w_j, b^l_{1ij}.w_j, b^m_{2ij}.w_j, b^l_{3ij}.w_j, b^u_{3ij}.w_j)$$

With i = 1, 2, 3, ..., n; and j = 1, 2, 3, . . ., n.

D = Weighted normalized decision matrix, d_{ij} = Matrix element D row to i column to j, $\tilde{w}_j$ = Criteria weight to j, b_{1ij}^{u} = Upper Point 1, b_{1ij}^{l} = Lower point 1, b_{2ij}^{ml} = Middle point 2, b_{2ij}^{mu} = Middle Point 2, b_{3ij}^{l} = Lower Middle 3, b_{3ij}^{u} = Upper Point 3

9. Calculate the distance of each alternative from the positive and negative ideal solutions. The distance of each alternative from positive ideal solution is denoted d_i^+ by the following[19]:

$$d_{i1}^{+}=\sum_{j=1}^{n}\sqrt{\frac{1}{3}\left[\left(d_{1ij}^{u}-1\right)^{2}+\left(d_{2ij}^{m}-1\right)^{2}+\left(d_{3ij}^{u}-1\right)^{2}\right]}, \tag{16}$$

$$d_{i2}^{+}=\sum_{j=1}^{n}\sqrt{\frac{1}{3}\left[\left(d_{ij1}^{l}-1\right)^{2}+\left(d_{ij2}^{m}-1\right)^{2}+\left(d_{ij3}^{l}-1\right)^{2}\right]}.$$

The distance each alternative from negative ideal solution is denoted by d_i^- which is expressed as follows:

$$d_{i1}^{-}=\sum_{j=1}^{n}\sqrt{\frac{1}{3}\left[\left(d_{1ij}^{u}-0\right)^{2}+\left(d_{2ij}^{m}-0\right)^{2}+\left(d_{3ij}^{u}-0\right)^{2}\right]}, \tag{17}$$

$$d_{i2}^{-}=\sum_{j=1}^{n}\sqrt{\frac{1}{3}\left[\left(d_{ij1}^{l}-0\right)^{2}+\left(d_{ij2}^{m}-0\right)^{2}+\left(d_{ij3}^{l}-0\right)^{2}\right]}.$$

t_{1ij}^{u} = Upper point of a row to i column to j , t_{1ij}^{l} = Lower point of a row to i column to j, t_{2ij}^{m} = Middle point of a row to i column to j, t_{3ij}^{l} = Lower point of a row to i column to j, t_{3ij}^{u} = Upper point of a row to i column to j, $\tilde{v}_j^+$ = Positif ideal solution matrix, $\tilde{v}_j^-$ = Negatif ideal solution matrix

10. Calculate relative proximity distance.

The relative proximity of the ideal solution can be denoted RC_i by which is expressed as follows:

$$RC_{i1}=\frac{d_{i1}^{-}}{d_{i1}^{+}+d_{i1}^{-}} \quad \text{and} \quad RC_{i2}=\frac{d_{i2}^{-}}{d_{i2}^{+}+d_{i2}^{-}} \tag{18}$$

The average relative proximity is denoted by RC_i which is stated as follows:

$$RC_i=\frac{RC_{i1}+RC_{i2}}{2}$$

with RC_{i1} : Upper limit relative proximity

RC_{i2} : Lower limit relative proximity

11. Alternative of ranking

The alternatives are sorted from RC_i the largest value to the smallest value. The alternative with the largest RC_i value is the best solution.

3.2. Implementation model hybrid interval type-2 FAHP and TOPSIS for mapping salt farmers

The stages of implementing salt farmer mapping are as follows:

1. Data Collection

At the stage of collecting this data consists of Data for salt farmers used is 2020 data, questionnaire data for 100 salt farmers in Sampang, Madura by filling in indicator questionnaires that are by the Covid-19 pandemic, Questionnaire data for the Marine and Fisheries Service of Sampang Madura, namely the level of importance assessment data and data on the relationship between the criteria that will be used for the weighting of salt farmers

2. Determine the criteria for mapping salt farmers. in this study, there are 6 criteria, namely land area (A1), number of workers (A2), capital (A3), production yield (A4), profit (A5), marketing system (A6).
3. Determine membership function each criterion assessment using the TFN function, as in Figure 2. Interval fuzzy type-2 membership function is used to determine the linguistic scale

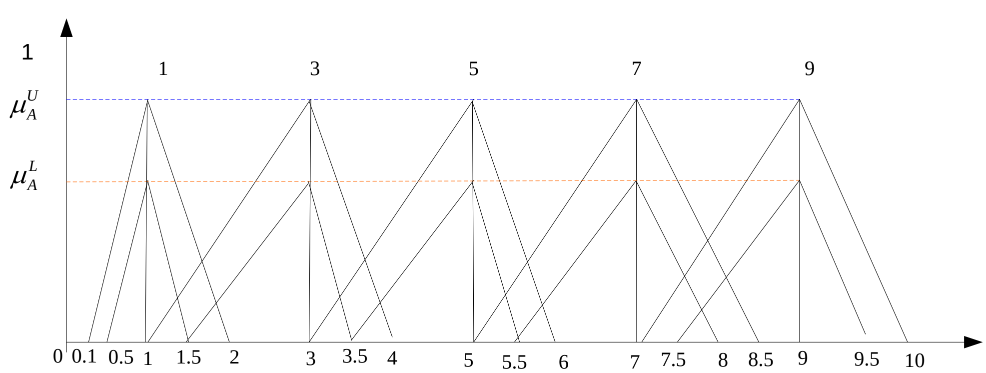

Figure 2. Interval fuzzy type-2 membership function for Criteria

4. Determining the linguistic scale of interval fuzzy type-2 using a numerical scale can be seen in Table 1. By using the same middle point on the Triangular Fuzzy Number (TFN).

Table 1. Linguistic Scale interval Type-2 Fuzzy

Numeric	Fuzzy Type-2 Scale	Linguistic Definition
	[(1,1) 1(1,1)]	Comparison of 2 Same Criteria
1	[(0.1, 0.5) 1 (1.5, 2)]	Equally Important
3	[(1, 1.5) 3 (3.5, 4)]	A Little More Important
5	[(3, 3.5) 5 (5.5, 6)]	More important
7	[(5, 5.5) 7 (8, 8.5)]	Very More Important
9	[(7, 7.5) 9 (9.5, 10)]	The most important

5. After determining the membership function of fuzzy TFN type-2 interval and the linguistic scale, the next step is to conduct a questionnaire to 3 assessors, namely fisheries and marine service, the head of a farmer group, and the salt expert team. because this research is based on a support system group, this study uses 3 assessors, as shown in Table 2, Table 3, Table 4. Next is to determine calculations of several raters using the Geometric Means Aggregation method, which is shown in Table 5. After determining Geometric Means Aggregation (GMA), proceed with calculating weighted normalization as in Table 6. The final step is the fuzzification process used to determine the weight of each Criteria in Table 7.

Table 2. Decision Maker 1

	A1					A2					…	A6				
	U1	**L1**	**M2**	**L3**	**U3**	**U1**	**L1**	**M2**	**L3**	**U3**	**…**	**U1**	**L1**	**M2**	**L3**	**U3**
A1	1	1	1	1	1	0.25	0.29	0.33	0.67	1	…	0.25	0.29	0.33	0.67	1
A2	1	1.5	3	3.5	4	1	1	1	1	1	**…**	0.25	0.29	0.33	0.67	1
A3	1	1.5	3	3.5	4	1	1.5	3	3.5	4	…	0.25	0.29	0.33	0.67	1
A4	3	3.5	5	5.5	6	1	1.5	3	3.5	4	**…**	0.25	0.29	0.33	0.67	1
A5	1	1.5	3	3.5	4	1	1.5	3	3.5	4	…	0.12	0.13	0.14	0.29	0.33
A6	1	1.5	3	3.5	4	1	1.5	3	3.5	4	**…**	1	1	1	1	1

Table 3. Decision Maker 2

	A1					A2					…	A6				
	U1	**L1**	**M2**	**L3**	**U3**	**U1**	**L1**	**M2**	**L3**	**U3**	**…**	**U1**	**L1**	**M2**	**L3**	**U3**
A1	1	1	1	1	1	0.25	0.29	0.33	0.67	1	…	0.25	0.29	0.33	0.67	1
A2	1	1.5	3	3.5	4	1	1	1	1	1	**…**	0.25	0.29	0.33	0.67	1
A3	3	3.5	5	5.5	6	1	1.5	3	3.5	4	…	0.25	0.29	0.33	0.67	1
A4	3	3.5	5	5.5	6	5	5.5	7	8	8.5	**…**	0.25	0.29	0.33	0.67	1
A5	1	1.5	3	3.5	4	1	1.5	3	3.5	4	…	0.25	0.29	0.33	0.67	1
A6	1	1.5	3	3.5	4	1	1.5	3	3.5	4	**…**	1	1	1	1	1

Table 4. Decision Maker 3

	A1					A2					…	A6				
	U1	**L1**	**M2**	**L3**	**U3**	**U1**	**L1**	**M2**	**L3**	**U3**	**…**	**U1**	**L1**	**M2**	**L3**	**U3**
A1	1	1	1	1	1	0.25	0.29	0.33	0.67	1	…	0.25	0.29	0.33	0.67	1
A2	1	1.5	3	3.5	4	1	1	1	1	1	**…**	0.25	0.29	0.33	0.67	1
A3	1	1.5	3	3.5	4	1	1.5	3	3.5	4	…	0.12	0.13	0.14	0.29	0.33
A4	3	3.5	5	5.5	6	3	3.5	5	5.5	6	**…**	0.17	0.18	0.20	0.29	0.33
A5	1	1.5	3	3.5	4	1	1.5	3	3.5	4	…	0.17	0.18	0.20	0.29	0.33
A6	1	1.5	3	3.5	4	1	1.5	3	3.5	4	**…**	1	1	1	1	1

Table 5. Results of interval type-2 Geometric means aggregation

	U1	**L1**	**M2**	**L3**	**U3**
A1	0.298	0.330	0.371	0.622	0.834
A2	0.383	0.445	0.549	0.857	1.114
A3	0.483	0.533	0.712	1.076	1.241
A4	0.805	0.947	1.256	1.560	1.777
A5	1.073	1.310	2.000	2.405	2.679
A6	1.273	1.684	2.874	3.235	3.565
Count	4.316	5.249	7.762	9.757	11.210

Table 6. Results of normalization of the same middle point

	A1	A1	A1	A1	A1
A1	0.0691	0.0629	0.0478	0.0638	0.0744
A2	0.0888	0.0848	0.0707	0.0879	0.0994
A3	0.1120	0.1016	0.0917	0.1103	0.1107
A4	0.1866	0.1804	0.1618	0.1599	0.1586
A5	0.2485	0.2496	0.2577	0.2465	0.2390
A6	0.2951	0.3207	0.3703	0.3316	0.3180
Count	1	1	1	1	1

Table 7. Results of same middle point defuzzification

Criteria	Lower limit	Upper Limit	Defuzzification
K1	0.05101	0.05817	0.05459
K2	0.06902	0.08111	0.07507
K3	0.08384	0.10120	0.09252
k4	0.13519	0.16738	0.15128
K5	0.19871	0.25127	0.22499
K6	0.26223	0.34087	0.30155

Based on Table 7. Defuzzification, the weight of criteria is as follows: land area (A1) = 0.05459, number of workers (A2) = 0.07507, capital (A3) = 0.09252, production output (A4) = 0.15128, profit (A5) = 0.22499, marketing system (A6) = 0.30155. The most influential indicator on measuring the performance of salt farmers is profit and marketing system and product output.

6. This step, interval type-2 FTOPSIS, the weight used in this method is found in step 4, namely weight of interval FAHP. The rules for each indicator of salt farmer mapping and salt farmer membership functions are listed in Table 8. The fuzzy type-2 interval membership function for alternative (Salt Farmer) in Figure 3. Determine same middle point linguistic scale for assessment of salt farmers can be seen in Table 9.

Table 8. Mapping Indicators for Salt Farmers

Code	Criteria	Value of Citeria	Description
A1	land area	<0.1 ha	Bad
		0.2-0.50 ha	Moderate
		0.75-0.10 ha	Good
		>=1.2 ha	Very Good
A2	Number of workers	1 People	Bad
		2-4 People	Moderate
		5-7 People	Good
		>10 People	Very Good
A3	capital	1-2 million	Bad
		2.5-3.5 million	Moderate
		4- 4.5 million	Good
		>=5 million	Very Good
A4	Production yield	1-5 tons	Bad
		6-10 tons	Moderate
		11-18 tons	Good
		>18 tons	Very Good
A5	Profit	2-3 million	Bad
		3.5-5 million	Moderate
		5.5-10 million	Good
		>=10 million	Very Good
A6	Marketing	Merchants, collectors	Bad
		Farmer, collector	Moderate
		Factory intermediary	Good
		Salt factory	Very Good

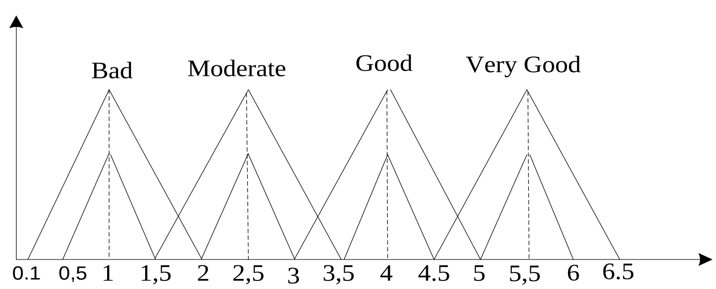

Figure 3. The fuzzy type-2 interval membership function for alternative (Salt Farmer)

Table 9. The Linguistic for Ratings same Middle Points

Linguistic Variables Ratings	Interval type-2 TFN Scale
Bad	[(0.1, 0.5) (1) (1.5, 2)]
Moderate	[(1.5, 2) (2.5) (3, 3.5)]
Good	[(3, 3.5) (4) (4.5, 5)]
Very Good	[(4.5, 5) (5.5) (6, 6.5)]

7. Determine the data for each salt farmer based on the results of the questionnaire to the salt farmer. the results of filling in the salt farmer data are in accordance with the 6 criteria for mapping salt farmers. Salt farmer data can be seen in Table 10. For indicators A1 and A2. Table 11. For indicators A3 and A4. Table 12. For indicators A13 and A14.

Table 10. Data for each salt farmer for criteria A1 and A2

No	Salt Farmer Name	A1					A2				
		U1	**L1**	**M2**	**L3**	**U3**	**U1**	**L1**	**M2**	**L3**	**U3**
1	Towwi	1.5	2	2.5	3	3.5	3	3.5	4	4.5	5
2	Jupriyanto	1.5	2	2.5	3	3.5	1.5	2	2.5	3	3.5
3	Mat Halih	0.1	0.5	1	1.5	2	1.5	2	2.5	3	3.5
4	Suharianto	3	3.5	4	4.5	5	3	3.5	4	4.5	5
5	Solihin	1.5	2	2.5	3	3.5	1.5	2	2.5	3	3.5
…	….	…	…	…	…	…	…	…	…	…	…
100	Msamer	3	3.5	4	4.5	5	3	3.5	4	4.5	5
	Weight of FAHP Interval	0.298	0.33	0.371	0.622	0.834	0.383	0.445	0.549	0.857	1.114

Table 11. Data for each salt farmer for criteria A3 and A4

No	Salt Farmer Name	A3					A4				
		U1	**L1**	**M2**	**L3**	**U3**	**U1**	**L1**	**M2**	**L3**	**U3**
1	Towwi	3	3.5	4	4.5	5	1.5	2	2.5	3	3.5
2	Jupriyanto	1.5	2	2.5	3	3.5	3	3.5	4	4.5	5
3	Mat Halih	1.5	2	2.5	3	3.5	1.5	2	2.5	3	3.5
4	Suharianto	3	3.5	4	4.5	5	3	3.5	4	4.5	5
5	Solihin	3	3.5	4	4.5	5	3	3.5	4	4.5	5
…	….	…	…	…	…	…	…	…	…	…	…
100	Msamer	1.5	2	2.5	3	3.5	1.5	2	2.5	3	3.5
	Weight of FAHP Interval	0.483	0.533	0.712	1.076	1.241	0.805	0.947	1.256	1.56	1.777

Table 12. Data for each salt farmer for criteria A5 and A6

No	Salt Farmer Name	A5					A6				
		U1	**L1**	**M2**	**L3**	**U3**	**U1**	**L1**	**M2**	**L3**	**U3**
1	Towwi	3	3.5	4	4.5	5	1.5	2	2.5	3	3.5
2	Jupriyanto	1.5	2	2.5	3	3.5	3	3.5	4	4.5	5
3	Mat Halih	0.1	0.5	1	1.5	2	0.1	0.5	1	1.5	2
4	Suharianto	4.5	5	5.5	6	6.5	4.5	5	5.5	6	6.5
5	Solihin	1.5	2	2.5	3	3.5	3	3.5	4	4.5	5
…	….	…	…	…	…	…	…	…	…	…	…
100	Msamer	3	3.5	4	4.5	5	3	3.5	4	4.5	5
	Weight of FAHP Interval	1.073	1.31	2	2.405	2.679	1.273	1.684	2.874	3.235	3.565

8. Determine the weighted normalization of all salt farmers against the salt farmer mapping indicators. The weighted normalization is shown in Table 13. The Weighted Normalization for Criteria A1 and A2. Table 14. The Weighted Normalization for Criteria A3 and A4. Table 15. The Weighted Normalization for Criteria A5 and A6

Table 13. The Weighted Normalization for Criteria A1 and A2

No	Salt Farmer Name	A1					A2				
		U1	**L1**	**M2**	**L3**	**U3**	**U1**	**L1**	**M2**	**L3**	**U3**
1	Towwi	0.45	0.66	0.93	1.87	2.92	1.15	1.56	2.20	3.86	5.57
2	Jupriyanto	0.45	0.66	0.93	1.87	2.92	0.57	0.89	1.37	2.57	3.90
3	Mat Halih	0.03	0.17	0.37	0.93	1.67	0.57	0.89	1.37	2.57	3.90
4	Suharianto	0.89	1.16	1.48	2.80	4.17	1.15	1.56	2.20	3.86	5.57
5	Solihin	0.45	0.66	0.93	1.87	2.92	0.57	0.89	1.37	2.57	3.90
…	….	…	…	…	…	…	…	…	…	…	…
100	Msamer	0.89	1.16	1.48	2.80	4.17	1.15	1.56	2.20	3.86	5.57

Table 14. The Weighted Normalization for Criteria A3 and A4

No	Salt Farmer Name	A3					A4				
		U1	**L1**	**M2**	**L3**	**U3**	**U1**	**L1**	**M2**	**L3**	**U3**
1	Towwi	1.45	1.87	2.85	4.84	6.21	1.21	1.89	3.14	4.68	6.22
2	Jupriyanto	0.72	1.07	1.78	3.23	4.34	2.42	3.31	5.02	7.02	8.89
3	Mat Halih	0.72	1.07	1.78	3.23	4.34	1.21	1.89	3.14	4.68	6.22
4	Suharianto	1.45	1.87	2.85	4.84	6.21	2.42	3.31	5.02	7.02	8.89
5	Solihin	1.45	1.87	2.85	4.84	6.21	2.42	3.31	5.02	7.02	8.89
…	….	…	…	…	…	…	…	…	…	…	…
100	Msamer	0.72	1.07	1.78	3.23	4.34	1.21	1.89	3.14	4.68	6.22

Table 15. The Weighted Normalization for Criteria A5 and A6

No	Salt Farmer Name	A5					A6				
		U1	**L1**	**M2**	**L3**	**U3**	**U1**	**L1**	**M2**	**L3**	**U3**
1	Towwi	3.22	4.59	8.00	10.82	13.40	1.91	3.37	7.19	9.71	12.48
2	Jupriyanto	1.61	2.62	5.00	7.22	9.38	3.82	5.89	11.50	14.56	17.83
3	Mat Halih	0.11	0.66	2.00	3.61	5.36	0.13	0.84	2.87	4.85	7.13
4	Suharianto	4.83	6.55	11.00	14.43	17.41	5.73	8.42	15.81	19.41	23.17
5	Solihin	1.61	2.62	5.00	7.22	9.38	3.82	5.89	11.50	14.56	17.83
…	….	…	…	…	…	…	…	…	…	…	…
100	Msamer	3.22	4.59	8.00	10.82	13.40	3.82	5.89	11.50	14.56	17.83

9. After determining the weighted normalization, then calculate the Positive Ideal Solution and Negative Ideal Solution. The results of the positive ideal solution can be seen in Table 16. and Table 17.

Table 16. Positive Ideal Solution

A1		A2		A3		A4		A5		A6	
D+	D+	D+	D+	D+	D+	D+	D+	D+	D+	7.546	6.315
1.154	0.539	2.73	1.82	3.199	2.512	3.259	2.511	8.318	7.265	11.564	10.294
1.154	0.539	1.71	0.93	1.989	1.363	5.176	4.389	5.371	4.368	3.735	2.475
0.771	0.605	1.71	0.93	1.989	1.363	3.259	2.511	2.632	1.625	15.634	14.297
1.852	1.079	2.73	1.82	3.199	2.512	5.176	4.389	11.315	10.184	11.564	10.294
1.154	0.539	1.71	0.93	3.199	2.512	5.176	4.389	5.371	4.368	7.546	6.315
…	…	…	…	…	…	…	…	…	…	…	…
1.852	1.079	2.73	1.82	1.989	1.363	3.259	2.511	8.318	7.265	11.564	10.294

Table 17. Negative Ideal Solution

A1		A2		A3		A4		A5		A6	
D-	D-	D-	D-	D-	D-	D-	D-	D-	D-	D-	D-
1.787	1.262	3.52	2.72	4.030	3.417	4.082	3.433	9.198	8.209	8.386	7.238
1.787	1.262	2.41	1.76	2.742	2.215	6.056	5.339	6.205	5.289	12.443	11.237
0.987	0.587	2.41	1.76	2.742	2.215	4.082	3.433	3.303	2.411	4.439	3.292
2.607	1.947	3.52	2.72	4.030	3.417	6.056	5.339	12.214	11.137	16.529	15.248
1.787	1.262	2.41	1.76	4.030	3.417	6.056	5.339	6.205	5.289	12.443	11.237
…	…	…	…	…	…	…	…	…	….	…	…
2.607	1.947	3.52	2.72	2.742	2.215	4.082	3.433	9.198	8.209	12.443	11.237

10. Calculate the relative proximity distance. The relative proximity of the ideal solution and average relative proximity is denoted by RC_i can be seen in can be seen in Table 18.

Table 18. The relative (RCi1, RCi2) and average (RCi) proximity of ideal solution

No	Salt Farmer	RCi1	RCi2	RCi
1	Towwi	0.458068	0.443729	0.450899
2	Jupriyanto	0.460036	0.446792	0.453414
3	Mat halih	0.439618	0.409858	0.424738
4	Suharianto	0.47024	0.462706	0.466473
5	Solihin	0.461044	0.448705	0.454874
…	….	…	…	…
100	Msamer	0.462046	0.449837	0.455942

11. Results Recommendations for salt farmers can be seen in Table. 19. The results of the recommendations stated that 45% received good recommendations, 35% entered into moderate recommendations and 20 % entered into bad recommendations.

Table 19. Recommendation Salt Farmer

No	Salt Farmer	Value of TFN with Fuzzy Type-2	Recommendation
1	Towwi	0.450899	Good
2	Jupriyanto	0.453414	Good
3	Mat Halih	0.424738	Bad
4	Suharianto	0.466473	Good
5	Solihin	0.454874	Good
7	Hanipah	0.443738	Moderate
8	Suibeh	0.445473	Moderate
9	Amin	0.443474	Moderate
10	Padiyanto	0.432238	Bad
11	Mashadi	0.434473	Bad
…	….	...	...
96	Masudin / Su'din	0.424738	Bad
97	Yasin	0.484323	Good
98	Durrahman	0.484544	Good
99	Sucipto	0.471874	Good
100	Msamer	0.455942	Good

CONCLUSION

The conclusion of this research is that indicators most influence recommendation salt farmer are marketing models, production yields and profit. The integration of interval fuzzy type-2 AHP and TOPSIS is suitable for salt farmer map recommendations and type-2 fuzzy interval method has a yield range between one alternative and another which is smaller than fuzzy type-1. The results of recommendations salt farmer stated that 45% received good, 35% entered into moderate and 20 % entered into bad recommendations. This research can be developed with different case studies and method can also be developed using a trapezoid fuzzy type-2.

ACKNOWLEDGMENT

We would like to thanks University of Trunojoyo Madura (UTM) for independent grants national collaborative research schemes with research contract number: 3130 /UN46.4.1/PT.01.03./2021

CONFLICT OF INTERESTS

The author(s) declare that there is no conflict of interests.

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