



Mapping the Marine Fisheries Sector of Regencies/Cities in East Java in 2016-2020 with Fuzzy K-Means Clustering Method

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Abstract—This research will create a marine fisheries sector business cluster in East Java in 2016-2020. The method used in this research is Fuzzy K-Means. The Fuzzy K-Means clustering method has several advantages, including being able to make clusters optimally and robust against several disturbances. The results of the cluster will then be used as a basis for identifying the potential and shortcomings of marine fisheries sector businesses in regencies/ cities in East Java. The mapping carried out resulted in 4 clusters with different characteristics. Sequentially, clusters A, B, C, and D are the clusters with the first highest, second highest, third highest, and lowest marine fishery business potential in East Java. The members of cluster A in 2016-2020 are Banyuwangi Regency, Lamongan Regency, Bangkalan Regency, and Sumenep Regency. Then the members of cluster B are Probolinggo Regency, Pasuruan Regency, Tuban Regency, Gresik Regency, Pamekasan Regency, and Probolinggo City. In cluster C, the members are Pacitan Regency, Malang Regency, Jember Regency, Situbondo Regency, Sidoarjo Regency, and Surabaya City. And in cluster D, are Tulungagung Regency, Blitar Regency, Lumajang Regency, and Pasuruan City. Meanwhile, cluster E contains 16 regencies/cities in East Java that do not have marine fisheries data.

Keywords— *fishery; fuzzy k-means; cluster*

I. INTRODUCTION

Indonesia has an ocean area that is wider than its land area with a total area of Indonesia's sea area of about 7.81 million km², a coastline of 95,181, km and thousands of islands with a

total of 17,499 [1]. This is the reason that Indonesia is one of the maritime countries. From the condition of the Indonesian territory, it can be said that the maritime sector is one of the strategic sectors in Indonesia and it is hoped that Indonesia can become a maritime country that is independent, advanced, strong, and based on national interests.

It is stated that there are 5 (five) main pillars in the maritime sector to realize the world maritime axis, one of which is maintaining and managing marine resources [2]. In developing and improving marine food sovereignty through the development of the fishing industry, it is hoped that the government and the community can work together. The fisheries sector has contributed quite a lot over the last 3 years, namely IDR 53,230.54 billion (in 2018), IDR 54,495.58 billion (in 2019), and IDR 54,964.27 billion (in 2020) [3].

East Java has a large enough opportunity for the development of capture fisheries business because it has the largest volume of marine capture fishery products in Indonesia. This is evidenced by the volume value of capture fisheries in 2019 which reached 487,332 tons [3]. Fish consumption in East Java has also exceeded the minimum standard of fish consumption in the world according to the FAO (Food and Agriculture Organization) of 30 kg/year, reaching 41.44 kg in 2019 [4]. If fish consumption in East Java is high, then fish production in East Java should ideally also be high. Capture fisheries production in East Java was the third highest in

Indonesia in 2017, reaching 440,981.6 tons per year [5]. Based on these data, it can be seen that the fisheries sector in East Java has considerable and interesting potential to be studied and developed.

Assessment of the distribution of fishery potential in regencies/ cities in East Java needs to be carried out in more depth because the potential of each region has not been described specifically, so an integrated system is needed so that later can provide added value for the local community of each regency/ city in Java. East in particular, and increase the rate of economic growth of East Java. This study will map the marine fisheries sector in regencies/ cities in East Java using the Fuzzy K-Means method which is one of the development clustering methods of K-Means by applying the fuzzy nature of its membership [6]. Research on Fuzzy K-Means has been conducted by Rifa'i (2020) to classify student thesis titles [7]. Sukim's research (2011) shows that the Fuzzy K-Means method is more robust in maintaining the number of clusters against outliers when compared to the K-Means method [8], [9].

It is important to map the capture fisheries business potential of regencies/ cities in East Java to provide benefits for related parties to make plans and policies that are appropriate and more focused because the handling will be adjusted to the characteristics of each regency/ city. In addition, the results of this mapping help business people to see a map of the potential of the marine fisheries sector to make the right strategy for the development of processed marine fishery products.

II. METHODOLOGY

Fuzzy K-Means method is a clustering method that belongs to non-hierarchical clustering, which was developed from K-Means by applying the fuzzy nature of its membership. The membership function variable used in the Fuzzy K-Means method refers to how likely it is that data can become a member of a cluster. Fuzzy K-Means introduces a variable m which is the weighting exponent of the membership function. These variables can change the magnitude of the influence of the membership function. In the clustering process using this method, m has a value area greater than 1 ($m > 1$). In optimizing clustering problems, the commonly used value of m is 2 although there is no clear provision regarding the optimal amount of m value.

Equation (1) is used to calculate the membership function for a data to a certain group [6].

$$u_{ik} = \sum_{j=1}^c \left[\left(\frac{D(x_k v_i)}{D(x_k v_j)} \right)^{\frac{2}{m-1}} \right]^{-1} \quad (1)$$

description:

u_{ik} = Membership function k data to i group

v_i = The value of the centroid of i group

v_j = The value of the centroid of j group

m = Weighting exponent

c = Number of clusters

Membership function has a value range of $0 \leq u_{ik} \leq 1$. Data items that have a higher probability of belonging to a group will

have a membership function value to that group that is close to 1 and the other group is close to 0, with the provision of, $1 < m < \infty, 0 \leq u_{ik} \leq 1, \sum_{i=1}^c u_{ik} = 1$

Fuzzy C-Means Algorithm [10]:

1. Determine the number of clusters, for example c
2. Determine the initial initiation of the partition matrix U
3. Calculate the centroid of each group
4. Calculate the distance space, which is the squared Euclidean distance with equation (2) as follows.

$$D_{ik} = D(x_k, v_i) = \sum_{i=1}^c \|x_k - v_i\|^2 = \sqrt{\sum_{i=1}^c (x_k - v_i)^2} \quad (2)$$

description:

D_{ik} = Distance between object and group center

x_{ik} = k variable

v_i = The value of the centroid (group center) i group

c = Number of clusters

5. Calculate the membership function value of each data to each group
6. If $|U^1 - U^{(l-1)}| < \epsilon$, then the process stops. However, if the change in the membership function value is still above the threshold value (ϵ), then return to step 3.

The research will be carried out at the Marine Electrical Laboratory, Shipbuilding Institute of Polytechnic Surabaya. The secondary data that will be used in the study are capture fisheries data from the Department of Marine Affairs and Fisheries, and fisheries sector data in regency/ city in East Java presented by East Java Central Bureau of Statistics.

Table I shows the research variables used in this study::

TABLE I. RESEARCH VARIABLES

No.	Variable	Unit
1	Fisherman/ Fish Farmer (X_1)	People
2	Fishing Household/ Company (X_2)	Unit(s)
3	Fishing Boat/ Vessel (X_3)	Unit(s)
4	Fishing Equipment (X_4)	Unit(s)
5	Fish Production Volume (X_5)	Ton(s)
6	Fish Production Value (X_6)	Rupiah
7	Fish Consumption Rate (X_7)	Kg(s)

The steps of analysis carried out in this research are:

1. Literature review
The literature review continues to be carried out during the research to increase the knowledge of the implementers of the activity. Literature review is carried out by reviewing books and articles that are relevant to the research being carried out.
2. Data Retrieval
Secondary data retrieval from the Department of Marine Affairs and Fisheries and East Java Central Bureau of Statistics, for all variables in each regency/ city in East Java a total of 29 regencies and 9 cities, so the total regencies/ cities that will be the object of research are 38 regions.

3. Establishing a cluster of fishery business potential using the Fuzzy K-Means method based on the data that has been collected previously. The formation of a business potential cluster is based on 7 (seven) mapping factors which include fishermen/ fish farmers, fishing households/ companies, number of fishing boats/ vessels, fishing equipment, fish production volume, fish production value in rupiah, and fish consumption rate.
4. Obtained the results of mapping the business potential from the previous step. The results of the mapping are divided into 4 (four) in each cluster in the capture fisheries sector. Because the observation period is 5 (five) years, the results obtained are 4 (four) clusters for marine fisheries clusters in 2016-2020 respectively.
5. Make data analysis and identify potentials and shortcomings of the marine fisheries sector in each regency/ city in East Java.

III. RESULT AND DISCUSSION

The following is an example of the results of mapping regencies/ cities in East Java in the marine fisheries sector in 2020 obtained from data processing using the RStudio software, as can be seen in Fig. 1

The number in the graph below shows regencies/ cities in East Java that have captured fisheries businesses in the marine fisheries sector. Members of cluster A are Banyuwangi Regency, Lamongan Regency, Bangkalan Regency, and Sumenep Regency. Members of cluster B are Probolinggo Regency, Pasuruan Regency, Tuban Regency, Sampang Regency, and Pamekasan Regency. Members of cluster C are Pacitan Regency, Tulungagung Regency, Malang Regency,

Situbondo Regency, Sidoarjo Regency, Gresik Regency, Probolinggo City, and Surabaya City. And members of cluster D are Trenggalek Regency, Blitar Regency, Lumajang Regency, Jember Regency, and Pasuruan City.

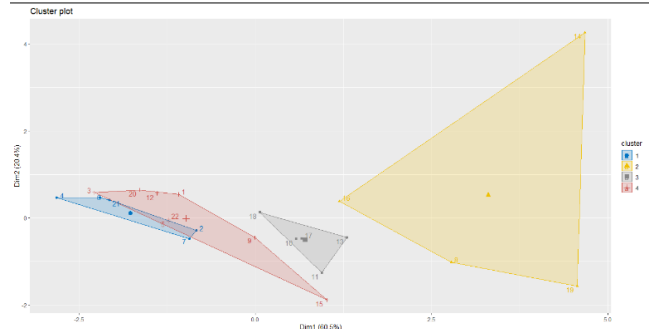


Fig. 1. Mapping Results of Marine Fisheries Sector in 2020

The results of the mapping of regencies/ cities in East Java in the marine fisheries sector based on data from the Department of Marine Affairs and Fisheries and "Jawa Timur dalam Angka" Publication 2016-2021, using Fuzzy K-Means Clustering, among others:

A. Cluster A

Cluster A is a cluster that has **the highest marine fishery business potential in East Java**. Based on its members, cluster A has the highest average scores of fishermen/ fish farmers, fishing households/ companies, number of fishing boats/ vessels, and fishing equipment compared to other clusters. Table II is the indicator value of Cluster A:

TABLE II. INDICATOR VALUE OF CLUSTER A

Indicator Value of Cluster A						
A	Mean 2016	Mean 2017	Mean 2018	Mean 2019	Mean 2020	Mean 2016-2020
X ₁	27,043.50	23,515.00	19,292.25	23,877.50	24,080.50	23,561.75
X ₂	5,789.75	5,068.00	5,096.25	4,830.75	4,830.75	5,123.10
X ₃	5,820.50	5,073.50	4,665.00	4,665.00	4,792.75	5,003.35
X ₄	23,473.00	18,204.25	53,703.50	154,886.75	149,472.00	79,947.90
X ₅	49,101.10	48,304.83	54,706.00	56,590.68	43,253.30	50,391.18
X ₆	Rp 723,996,951.75	Rp 783,526,530.55	Rp 921,502,018.93	Rp 974,454,832.25	Rp 741,192,012.00	Rp 828,934,469.10
X ₇	28.87	41.38	42.66	42.31	47.33	40.51

The average of the volume of fish production and the value of fish production in cluster A is the highest value compared to other clusters, which is 50,391.18 tons and Rp828,934,469.10. The marine fishery business potential in this cluster is supported by the high fish consumption rate, with an average value of 40.51 tons. The following are members of cluster A of the marine fisheries cluster:

1) 2016

Cluster A members in 2016 are Banyuwangi Regency, Lamongan Regency, Bangkalan Regency, and Sumenep Regency.

2) 2017

Cluster A members in 2017 are Banyuwangi Regency, Lamongan Regency, Bangkalan Regency, and Sumenep Regency.

3) 2018

Cluster A members in 2018 are Banyuwangi Regency, Lamongan Regency, Bangkalan Regency, and Sumenep Regency.

4) 2019

Cluster A members in 2019 are Banyuwangi Regency, Lamongan Regency, Bangkalan Regency, and Sumenep Regency.

5) 2020

Cluster A members in 2020 are Banyuwangi Regency, Lamongan Regency, Bangkalan Regency, and Sumenep Regency.

B. Cluster B

Cluster B is a cluster that has **the second highest marine fishery business potential in East Java**. Based on its members, cluster B has an average score of fishermen/ fish farmers, fishing households/ companies, and the number of fishing boats/ vessels used, the second highest. Table III is the indicator value of Cluster B:

TABLE III. INDICATOR VALUE OF CLUSTER B

Indicator Value of Cluster B						
B	Mean 2016	Mean 2017	Mean 2018	Mean 2019	Mean 2020	Mean 2016-2020
X ₁	5,118.25	5,779.25	9,429.71	11,023.71	12,398.00	8,749.79
X ₂	1,583.25	2,240.75	4,684.43	4,786.57	4,132.60	3,485.52
X ₃	1,370.50	1,950.50	2,579.71	3,391.71	3,330.40	2,524.57
X ₄	2,087.25	2,145.50	11,357.00	7,221.57	6,294.00	5,821.06
X ₅	18,293.68	21,221.15	20,695.04	20,202.49	21,410.40	20,364.55
X ₆	Rp 311,854,102.50	Rp 388,384,473.90	Rp 311,926,225.56	Rp 359,134,014.00	Rp 372,248,531.40	Rp 348,709,469.47
X ₇	28.05	35.28	38.09	39.59	45.76	37.35

The average fish production volume and fish production value of cluster B is 20,364.55 tons and Rp348,709,469,47. Fish production can increase if it is supported by adequate human resources and production facilities. The potential for marine fisheries business in this cluster is also supported by a fairly high fish consumption rate, with an average value of 37.35 tons. The following are members of cluster B of the marine fisheries cluster:

1) 2016

Cluster B members in 2016 are Gresik Regency, Pamekasan Regency, Probolinggo City, and Surabaya City.

2) 2017

Cluster B members in 2017 are Probolinggo Regency, Pasuruan Regency, Gresik Regency, and Probolinggo City.

3) 2018

Cluster B members in 2018 are Trenggalek Regency, Probolinggo Regency, Pasuruan Regency, Tuban Regency, Gresik Regency, Pamekasan Regency, and Probolinggo City.

4) 2019

Cluster B members in 2019 are Probolinggo Regency, Pasuruan Regency, Tuban Regency, Gresik Regency, Sampang Regency, Pamekasan Regency, and Probolinggo City.

5) 2020

Cluster B members in 2020 are Probolinggo Regency, Pasuruan Regency, Tuban Regency, Sampang Regency, and Pamekasan Regency.

C. Cluster C

Cluster C is a cluster that has **the third highest marine fishery business potential in East Java**. Based on its members, cluster C has an average score of fishermen/ fish farmers, fishing households/ companies, and the number of fishing boats/ vessels used, which is quite low. Table IV is the indicator value of Cluster C:

TABLE IV. INDICATOR VALUE OF CLUSTER C

Indicator Value of Cluster C						
C	Mean 2016	Mean 2017	Mean 2018	Mean 2019	Mean 2020	Mean 2016-2020
X ₁	12,424.29	7,781.00	7,081.60	6,625.00	5,193.88	7,821.15
X ₂	4,187.00	3,496.88	1,980.40	2,224.71	2,408.00	2,859.40
X ₃	2,730.86	1,748.75	1,608.80	1,643.14	1,891.25	1,924.56
X ₄	3,743.14	2,642.00	100,890.60	2,890.14	13,965.88	24,826.35
X ₅	12,638.53	13,227.59	10,741.90	14,578.43	11,276.99	12,492.69

Indicator Value of Cluster C						
C	Mean 2016	Mean 2017	Mean 2018	Mean 2019	Mean 2020	Mean 2016-2020
X ₆	Rp 160,688,393.71	Rp 174,487,560.70	Rp 174,959,584.86	Rp 193,790,727.14	Rp 190,727,051.13	Rp 178,930,663.51
X ₇	21.68	34.57	38.14	32.62	39.32	33.27

The average of the volume of fish production and the value of fish production in cluster C is a fairly low, which is 12,492.69 tons and Rp. 178,930,663.51. Fish production can increase if it is supported by adequate human resources and production facilities. In this cluster, the average number of fishing equipment used is quite high, as many as 24,826 units. The following are members of Cluster C of the marine fisheries cluster:

1) 2016

Cluster C members in 2016 are Pacitan Regency, Jember Regency, Situbondo Regency, Probolinggo Regency, Pasuruan Regency, Sidoarjo Regency, and Tuban Regency.

2) 2017

Cluster C members in 2017 are Pacitan Regency, Trenggalek Regency, Malang Regency, Jember Regency, Sidoarjo Regency, Sampang Regency, Pamekasan Regency, and Surabaya City.

3) 2018

Cluster C members in 2018 are Pacitan Regency, Jember Regency, Sidoarjo Regency, Sampang Regency, and Surabaya City.

4) 2019

Cluster C members in 2019 are Trenggalek Regency, Tulungagung Regency, Malang Regency, Jember Regency, Situbondo Regency, Sidoarjo Regency, and Surabaya City.

5) 2020

Cluster C members in 2020 are Pacitan Regency, Tulungagung Regency, Malang Regency, Situbondo Regency, Sidoarjo Regency, Gresik Regency, Probolinggo City, and Surabaya City.

D. Cluster D

Cluster D is a cluster that **has the lowest marine fishery business potential in East Java**. Based on its members, cluster D has the lowest average score for fishermen/ fish farmers, fishing households/ companies, and the number of fishing boats/ vessels used. Table V is the indicator value of Cluster D:

TABLE V. INDICATOR VALUE OF CLUSTER D

Indicator Value of Cluster D						
D	Mean 2016	Mean 2017	Mean 2018	Mean 2019	Mean 2020	Mean 2016-2020
X ₁	5,964.14	6,671.67	4,125.50	2,023.75	5,288.20	4,814.65
X ₂	1,117.86	1,360.67	1,479.00	1,067.75	1,561.40	1,317.33
X ₃	1,012.29	1,314.50	1,444.50	678.50	1,178.20	1,125.60
X ₄	1,581.57	2,007.67	4,230.50	22,643.50	2,569.00	6,606.45
X ₅	4,602.93	5,153.72	8,426.85	6,812.23	8,245.94	6,648.33
X ₆	Rp 65,177,165.43	Rp 52,692,643.97	Rp 62,074,217.28	Rp 70,993,937.00	Rp 71,454,112.00	Rp 64,478,415.14
X ₇	20.60	32.44	31.56	29.37	34.07	29.61

The average fish production volume and fish production value of cluster D is the lowest value, which is 6,648.33 tons and Rp. 64,478,415.14. The fish consumption rate of cluster D is also low, so it is necessary to improve or increase the condition of the marine fishery's business environment. The following are members of cluster D of the marine fisheries cluster:

1) 2016

Cluster D members in 2016 are Trenggalek Regency, Tulungagung Regency, Blitar Regency, Malang Regency, Lumajang Regency, Sampang Regency, and Pasuruan City..

2) 2017

Cluster D members in 2017 are Tulungagung Regency, Blitar Regency, Lumajang Regency, Situbondo Regency, Tuban Regency, and Pasuruan City.

3) 2018

Cluster D members in 2018 are Tulungagung Regency, Blitar Regency, Malang Regency, Lumajang Regency, Situbondo Regency, and Pasuruan City.

4) 2019

Cluster D members in 2019 are Pacitan Regency, Blitar Regency, Lumajang Regency, and Pasuruan City.

5) 2020

Cluster D members in 2020 are Trenggalek Regency, Blitar Regency, Lumajang Regency, Jember Regency, and Pasuruan City.

E. Cluster E

Cluster E is a cluster whose members do not have marine fisheries data where the data is used as a reference or mapping factor in this study. There are 16 regencies/ cities in East Java that do not have marine fisheries data, namely: Ponorogo Regency, Kediri Regency, Bondowoso Regency, Mojokerto Regency, Jombang Regency, Nganjuk Regency, Madiun Regency, Magetan Regency, Ngawi Regency, Bojonegoro Regency, Kediri City, Kota Blitar, Malang City, Mojokerto City, Madiun City, and Batu City.

IV. CONCLUSION

Based on the results of the research that has been done, the following conclusions can be drawn:

1. Cluster A

Cluster A has **the highest marine fishery business potential in East Java**. The regencies/ cities that have always been members of cluster A in the marine fisheries cluster in 2016-2020 are Banyuwangi Regency, Lamongan Regency, Bangkalan Regency, and Sumenep Regency.

2. Cluster B

Cluster B has **the second highest marine fishery business potential in East Java**. Regencies/ cities that often become members of cluster B in the marine fisheries cluster in 2016-2020 are Probolinggo Regency, Pasuruan Regency, Tuban Regency, Gresik Regency, Pamekasan Regency, and Probolinggo City.

3. Cluster C

Cluster C has **the third highest marine fishery business potential in East Java**. Regencies/ cities that are often members of cluster C in the marine fisheries cluster in 2016-2020 are Pacitan Regency, Malang Regency, Jember Regency, Situbondo Regency, Sidoarjo Regency, and Surabaya City.

4. Cluster D

has **the lowest marine fishery business potential in East Java**. Regencies/ cities that are often members of cluster D in the marine fisheries cluster in 2016-2020 are Tulungagung Regency, Blitar Regency, Lumajang Regency, and Pasuruan City.

5. Cluster E

Regencies/ cities that are members of cluster E in the marine fisheries cluster in 2016-2020 are Ponorogo Regency, Kediri Regency, Bondowoso Regency, Mojokerto Regency, Jombang Regency, Nganjuk Regency, Madiun Regency, Magetan Regency, Ngawi Regency, Bojonegoro Regency, Kediri City, Blitar City, Malang City, Mojokerto City, Madiun City, and Batu City.

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