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Analysis of Livestock Meat Production in Indonesia Using Fuzzy C-Means Clustering

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Abstract

The production of livestock in Indonesia is one type of food that the public can consume. Indonesia is still importing meat for food for its people. This study aims to classify provinces in Indonesia with high livestock meat production and low livestock meat production so that the government can maximize areas with high livestock meat production and can seek to increase livestock meat production in areas with low production. Clustering is needed to identify groups of livestock meat-producing provinces with high and low production. The data is grouped into 2 clusters using FCM with a silhouette index value of 0.95664, the first cluster with the highest meat production total in three provinces (West Java, Central java and east Java) and the second cluster with the lowest meat production total 31 provinces. West Java, Central java and east Java mostly work as livestock breeders due to the availability of sufficient land.

Keywords: *Province in Indonesia, Livestock Meat Production, Fuzzy C-Means, Clustering, Silhouette Index*

1. Introduction

The current era of globalization is causing the trade goods flow and services to expand beyond the region or country boundaries. Indonesia is a country with substantial food production and market capacity and is obliged to meet the food needs of its people in a sovereign and independent manner. Food exports and imports are central government policies regulated explicitly by the Minister of Trade and non-government [1].

The need and shortage of meat for public consumption always occur every year. The production of livestock meat has an essential role for the country's economy, but currently, livestock meat production is in a state of deficit, which causes the government to import. The availability of animal protein sources on a national scale can see from the population development and production of livestock meat. Indonesia's territory, which is the primary source of livestock meat production, is the island of Java [2].

Public consumption is one of the supporting factors for the formation of gross domestic commodities. According to Rodhiyah and Anggita, the most significant public food consumption is an animal protein or protein from livestock. Therefore, livestock products are high-value commodities [3]. Many livestock in Indonesia whose production is in meat includes cows, Goats, buffalo, chickens, horses, and sheep. According to the book Animal Business Data 2020 by Dr. Ir. Rochadi Tawaf MS et al. at agribusinessnetwork.com said that the largest population of livestock production was on the island of Java.

The Fuzzy C-Means (FCM) method is a data grouping technique where each point in the cluster is determined by the degree of membership [4]. The number of clusters of the Fuzzy C-Means algorithm that will be formed needs to be known in advance. Therefore this algorithm can be called a supervised grouping [5]. J. C. Bezdek first introduced this technique in 1981. The output of FCM produces information that can be used in building a fuzzy inference system [6].

Fuzzy C-Means clustering algorithm will group objects based on their similar characteristics into several classes [7]. Each object has high similarity in one cluster, while objects in one cluster with objects in other clusters have low similarity [8].

Rahman Syarif et al. proved the superiority of fuzzy c-means over k-means in a study entitled Comparison of the K-Means Algorithm and the Fuzzy C Means (FCM) Algorithm in GPS-Based Transportation Mode Clustering. Silhouette Index values for the Fuzzy C-Means clustering are more significant and tend to be more consistent than the accuracy values and the silhouette index values for the K-Means Clustering method [9].

Herlina et al. also compared fuzzy c-means compared to the Gaussian Mixture Model algorithm in their research entitled Comparison of the Fuzzy C-Means (FCM) Algorithm and Mixture Algorithm in Clustering Rainfall Data in Bengkulu City. Fuzzy C-Means is a suitable method that can be used as a decision supporter in grouping data with large enough dimensions because the data grouping is based on the degree of membership to improve the resulting cluster center in achieving the minimization of the target function that describes the distance from the data points. Given the center of the cluster to find the best location can be done faster, which is indicated by stopping the iteration [10]. The data of livestock meat production has also been applied using the k-means method to see the proximity of the data in one cluster using the silhouette index test. After doing the experiment using k-means, the silhouette index value of k-means is obtained with 2 clusters is 0.9294 and 3 clusters is 0.6829. It is known that the k-means silhouette index value is smaller than the silhouette index value obtained from the fuzzy c-means method. Therefore, the fuzzy c-means clustering method was chosen to be used in this study.

Research on grouping or clustering has been widely carried out in a study. Research on Fuzzy C-Means Clustering has been applied to various fields, including agriculture [11] [12] [13], economics [4] [14], disease detection [6] [7] and so on, so that Fuzzy C -Means is an algorithm that is reliable enough to solve problems related to object classification or clustering.

The level of national protein consumption is increasing every year, especially meat consumption, while the government imports livestock meat for food consumption for its people. This study aims to help the government optimize domestic meat production, hoping that the government can maintain areas in Indonesia with high meat production and increase areas with low production. These efforts can increase domestic meat production and reduce the number of meat imports that the government has carried out.

2. Literature Review

Farm

Food development is influenced by two factors, namely land and production factors. The production factors are influenced by seeds or seedlings, fertilizers, the number of livestock, and financing factors. It plays an essential role in the socio-cultural life of the Indonesian people [1]. Before the 1970s, almost most Indonesian farmers owned livestock. Even at that time, Indonesia was also able to export cattle and buffalo to several countries.

Java Island is the center of livestock meat production, with 56.3% of the total national livestock meat production [15]. Monthly per capita expenditure according to consumption of meat, eggs, milk, and fish or animal protein groups in 2015 was 18.6% and in 2016 was 17.84%, it can be seen from the explanation above that from 2015 to 2016, there was a decrease in consumption of food sources of animal protein [3].

The government has been trying to target meat self-sufficiency as a source of protein by increasing animal food production for more than ten years. The level of animal protein consumption in Indonesia only reaches 4.7 grams/person/day, meaning that Indonesian society's level of animal protein consumption is still much lower than other countries. The Philippines, Thailand, and Malaysia have averaged over 10 grams/person/day. Then in Japan, Australia, and New Zealand, which are developed countries, the average consumption of animal protein has reached above 20 grams/capita/day [16].

The need for food from livestock meat always increases every year. The government imports livestock meat, especially beef, to meet the food needs of its people. The Indonesian government is committed to 2026 not import livestock meat and focus on increasing the domestic livestock meat population [2].

Fuzzy C-Means Clustering

Fuzzy C-Means clustering (FCM) is a data clustering technique in which the existence of each data point in a cluster is determined by the degree of membership [17]. FCM uses a fuzzy grouping model with a fuzzy index using Euclidean Distance so that the data can be members of all classes or clusters formed with different degrees of membership between 0 to 1 [14].

The advantage of the FCM method is that the placement of the cluster center is more precise compared to other cluster methods [17]. Fuzzy C-Means is an algorithm that used to solve problems related to object classification or clustering [11].

Fuzzy C-Means clustering is one of many clustering methods that are part of Soft Clustering [18]. The output of Fuzzy C-Means clustering is not included in the fuzzy inference system but is in the form of membership degrees and centroids (cluster centers). These two components can be used to build a fuzzy inference system [13].

The initial process of FCM is to determine the center of the cluster. In this condition, the center of the cluster is not necessarily correct [19]. Each data has a degree of membership in each cluster [8]. Repeatedly, the membership value and the cluster center can be improved so that the cluster center will occupy the correct point. The algorithm of Fuzzy C-Means is as follows [11]:

a. The data to be clustered to X is in the form of a matrix of size n*m. With the following information.
   m: attributes on each data
   n: many samples of data
   Xij: sample data to j

b. Determine w (Rank), ξ (Error Rate), t=1 (Initial Iteration), c (Num of *Cluster*), MaxIter (Max Iteration), $P_0 = 0$ (Initial objective function).

c. Generating a random number where k is 1,2, …, c and i is 1,2,…, n being the members of a matrix whose initial partition is U.
   Counting the number in each column:

$$Q_i = \sum_{k=1}^{c} \mu_{ik} \quad (1)$$

   j = 1,2,…, n

   Calculate :

$$\mu_{ik} = \frac{\mu_{ik}}{Q_i} \quad (2)$$

   Q_i = The number of each column
   μ_{ik} = Random Number

d. Calculates the center of the cluster, kj where is 1, 2, …, m and is 1, 2, …, n

$$V_{kj} = \frac{\sum_{i=1}^{n}((\mu_{ik})^{w} * X_{ij})}{\sum_{i-1}^{n}(\mu_{ik})^{w}} \quad (3)$$

e. Calculates the objective function during the t-th iteration called P_t

$$P_t = \sum_{i=1}^{n} \sum_{k=1}^{c} \left(\left[\sum_{j=1}^{m} (X_{ij} - V_{kj})^2 \right] (\mu_{ik})^{w} \right) \quad (4)$$

   P_t = The objective function when iteration t

f. Calculating changes to the partition matrix

$$\mu_{ik} = \frac{\left[\sum_{j=1}^{m}(X_{ij}-V_{kj})^2\right]^{\frac{-1}{w-1}}}{\sum_{k=1}^{c}\left[\sum_{j=1}^{m}(X_{ij}-V_{kj})^2\right]^{\frac{-1}{w-1}}} \quad (5)$$

   With *k* is 1,2,…,*c* and *i* is 1,2,…,*n*

   Check the condition at the time of stopping. If (t is more than Maxlter) or ($|Pt - P_{t-1}|$ less than ξ), the iteration will stop, and if the iteration does not meet the conditions t+1 = t, repeat the fourth step.

Silhouette Index

Knowing the correct number of clusters when performing cluster analysis is not easy. One technique for validating the accuracy of cluster results is using a silhouette index. This test shows how precise the features and structures that used are so they can find out whether the data is in the right cluster [20].

The Silhouette coefficient is used to see the quality and cluster strength, measure the proximity of the data to the cluster and measure the distance between the data and the clusters. This method is a combination of cohesion and separation methods [21]. Silhouette index test is a test model that is also often used to validate the closeness of the relationship between objects in a cluster to determine the distance between clusters and the accuracy of the index in each cluster [22]. Silhouette index test can determine the quality and strength of the cluster and how well the object is in the cluster.

The silhouette index value ranges from -1 to 1 [12]. If the silhouette index value is close to -1 or less than 0, the object is in the wrong cluster. If the silhouette index is greater than 0 or close to 1, then the object is in the right cluster, and if the silhouette index is equal to 0, then the object is between 2 clusters [23]. The Silhouette index Test Formula is:

$$S(x_c) = \frac{1}{N} \sum_{i=1}^{N} S(x_i) \quad (6)$$

Silhouette Coefficient value formula in general:

$$SC = \frac{1}{k} \sum_{c=1}^{N} S(x_c) \quad (7)$$

Silhouette Coefficient value formula with equation:

$$S(x_i) = \frac{b_c - a_c}{\max[b_c, a_c]} \quad (8)$$

Where:
a_c = mean similarity of object i in 1 cluster.
b_c = mean similarity of object in each cluster other than the cluster where i belongs.
$S(x_i)$ = width of the i silhouette cluster.
N = number of data
K = number of *cluster*

3. Research Method

This study relied on numerical data from Indonesian livestock meat production. The data is taken from the official website of the Central Statistics Agency. Table 1 is dataset that will be used in this study. The data used in this study is data on livestock meat production in 34 provinces in Indonesia in 2020, which included four variables: beef, goat, chicken, and duck. The method used in this research is Fuzzy C-Means clustering [14].

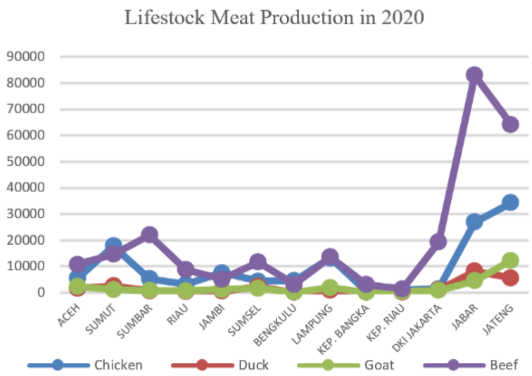


Fig. 1. The plot of sample data

The variable *x* in the data used in this study is 34 provinces in Indonesia. Meanwhile, the *y* variable in the data used in this study is the amount of livestock meat production in 2020. The plot of the data can be seen in Figure 1.

Table 1. Data for livestock meat production

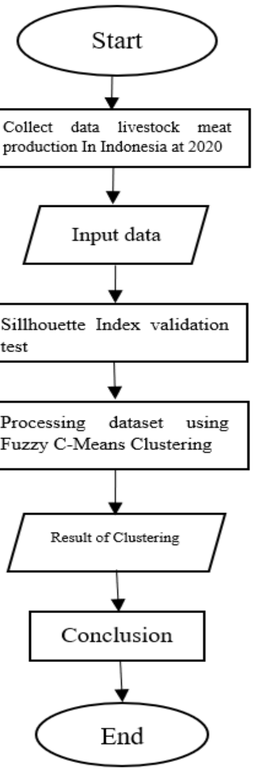
No	Provinces	Chicken	Duck	Goat	Beef
1	Aceh	5549	1697	2276	10740
2	North Sumatera	17853	2577	1187	14570
3	West Sumatera	5309	693	733	22022
4	Riau	3113	256	705	8611
5	Jambi	7589	531	1141	5094
6	South Sumatera	4353	2354	1697	11615
7	Bengkulu	4557	68	114	3149
8	Lampung	13224	767	1921	13522
9	Bangka Island	555	59	77	3015
10	Riau Island	1061	24	472	1401
11	Jakarta	1412	1094	842	19195
12	West Java	26943	8122	4454	82948
13	Central Java	34201	5598	12177	64154
14	Yogyakarta	5317	429	1769	7338
15	East Java	50562	9881	25995	105874
16	Banten	4123	1373	4331	41394
17	Bali	3313	324	991	9081
18	NTB	11640	1169	323	10962
19	NTT	11810	178	2921	13116
20	West Kalimantan	3207	292	421	5404
21	Central Kalimantan	2235	175	222	3851
22	South Kalimantan	2803	1642	271	6458
23	East Kalimantan	5075	139	573	7489
24	North Kalimantan	1311	20	101	591
25	North Sulawesi	2772	140	131	3484
26	Central Sulawesi	8540	896	1409	5011
27	South Sulawesi	26458	2892	1143	18184
28	Sotheast Sulawesi	12013	390	314	4405
29	Gorontalo	2472	54	229	1924
30	West Sulawesi	5871	226	184	2175
31	Maluku	267	48	235	2193
32	North Maluku	1117	87	78	860
33	West Papua	1613	59	74	1970
34	Papua	4901	108	293	3827

The steps in this research include:

a. Looking for data as a research reference and also research references related to clustering.

b. The second stage is collecting data on livestock meat production.
c. Perform Silhouette index Validation Test on production data.
d. We are processing the clustering data using the Fuzzy C-Means clustering method.
e. The final result of the Fuzzy C-Means process is obtained.

The following is a Flowchart of the research steps:



4. Result and Analysis

Silhouette Index Test

Silhouette index (SI) test is used to determine whether the data is correct in the cluster. The average silhouette index value describes the evaluation of the clustering results that have been carried out. It can also be used to select the appropriate cluster [23]. The criteria for the silhouette index structure are based on the average value, namely, in the interval, 0.7 – 1.0 is a strong structure, 0.51 – 0.69 is a reasonable structure, 0.26 – 0.49 is a weak structure, and less than 0.25 is a no structure [6].

In Table 1, the data has been calculated with the help of RStudio software. The data is processed using the Fuzzy C-Means Clustering method, and then the silhouette index test is carried out to determine the number of clusters with the best value to be used in this study. In Table 2, there are four silhouette index values from 2 clusters to 5 clusters. With this value, it can seem that the best silhouette index value is in the cluster of 2. With this value, it concluded that the best silhouette index value is in clusters of 2. Silhouette index with 2 clusters has a value of 0.95664, which means that each object is in the correct cluster. So, in this study, the results of meat production into 2 clusters.

Table 2. Result of Silhouette index validation test

	2 *Cluster*	3 *Cluster*	4 *Cluster*	5 *Cluster*
SI	0,95664	0,74562	0,70499	0,73776

The object is already in the right cluster with the silhouette index value of 2 clusters in Table 2. If 3, 4, or 5 cluster experiments, the results are not as good as using 2 clusters. Figure 2 below results from plotting the Silhouette index test on meat production data in 2020 using 2 clusters. Figure 2 explains that the Silhouette Index validation test for data on livestock meat production in 34 provinces in Indonesia with 2 clusters using the Fuzzy C-Means Clustering method has a good value for each index.

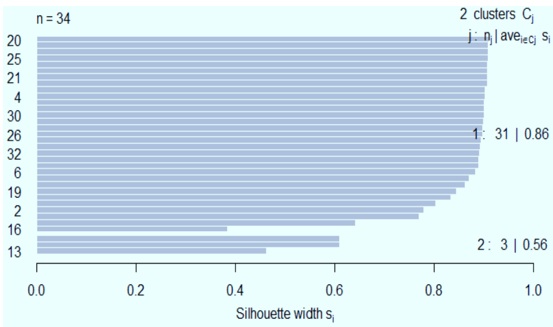


Fig. 2. The plot of silhouette index result

Figure 2 explains that the silhouette index value obtained in this study is quite good because there are no lines to the left of the zero point or a minus value. The digits 13, 16, 2,... 34 in Figure 2 represent the position of the point for each data in Table 1.

The Calculation Result

The data used in this study is quantitative data from livestock meat production in 34 provinces in Indonesia in 2020 with four livestock meat products, namely chicken, duck, goat, and beef, taken from the official website of BPS Indonesia.

The grouping in this study uses Fuzzy C-Means Clustering because the dimensions of the data used are pretty significant. The dataset in Table 1, grouped using the Fuzzy C-Means clustering method so that the following results are obtained:

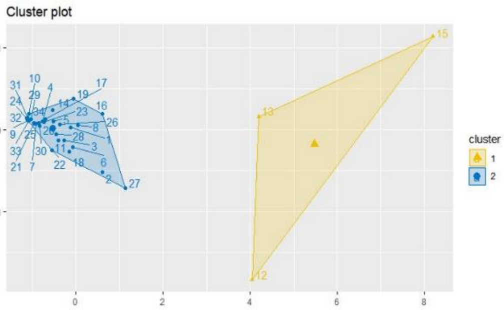


Fig. 3. *Cluster* Plot of livestock meat production in 2020.

The clustering results are shown in Figure 3. Numbers 1, 2, 3,... 34 in Figure 3 represent the point positions for each data in Table 1. For example, number 12 in Figure 3 shows that the 12th data in Table 1 is province West Java. West Java is around the yellow area or around cluster 1, which means the data is included in the high cluster. Number 27 in Figure 3 shows that the 27th data in Table 1 is province South Sulawesi. South Sulawesi is around the blue area or around cluster 2, which means the data is included in the low cluster, and so on.

In Figure 3 the yellow graph represents cluster 1 because the data points are quite close together, with the results obtained in cluster 1 totaling 3 provinces. While the blue graph represents cluster 2 because the data points are very close to each other, with the results obtained in cluster 2 totaling 31 provinces.

1. *Cluster* 1: West Java, Central Java and East Java
2. *Cluster* 2: Aceh, North Sumatra, West Sumatra, Riau, Jambi, South Sumatra, Bengkulu, Lampung, Bangka Belitung islands, Riau islands, Jakarta, DI Yogyakarta, Banten, Bali, NTB, NTT, West Kalimantan, East Kalimantan, Central Kalimantan, South Kalimantan, North Kalimantan, North Sulawesi, Central Sulawesi, South Sulawesi, Southeast Sulawesi, Gorontalo, West Sulawesi, Maluku, North Maluku, West Papua and Papua.

Next, to determine the province group with low and high livestock meat production, it can be analyzed from the cluster center (centroid). Centroids with a high value will be a group of provinces with high livestock meat production. Meanwhile, Centroids with a low value will be a group of provinces with low livestock meat production. The centroid value will be calculated using formula 3. The centroid value of each cluster with each commodity is shown in Table 3.

Table 3. The centroid of livestock meat production

Cluster	Chicken	Duck	Goat	Beef
1	35875,4	7665,1	13562,8	82753,6
2	5733,4	642,51	824,9	7846,4

For chicken commodity, it that cluster 1 > cluster 2, then the province in cluster 1 has higher meat production than the province in cluster 2, which has low meat production. For duck commodities, it can be seen at Table 3 that cluster 1 > cluster 2 means that the province in cluster 1 has higher meat production than the province in cluster 2, which has low meat production.

For Goat commodity, it can be seen at Table 3 that cluster 1 > cluster 2 means that the province in cluster 1 has higher meat production than the province in cluster 2, which has low meat production. For beef commodities, it can be seen at Table 3 that cluster 1 > cluster 2, then the province in cluster 1 has higher meat production than the province in cluster 2, which has low meat production.

Figure 3 shows the results of clustering with two clusters depending on the data's proximity. The yellow dots in Figure 3 represent Cluster 1, which contains data from provinces with high animal meat production and the blue dots represent Cluster 2, which contains data from provinces with low livestock meat production. Chickens, ducks, goats, and cows are among the livestock mentioned in this report. This suggests that provinces in cluster 1 or clusters with a lot of livestock meat produce more chicken, duck, goat, and beef than provinces in cluster 2.

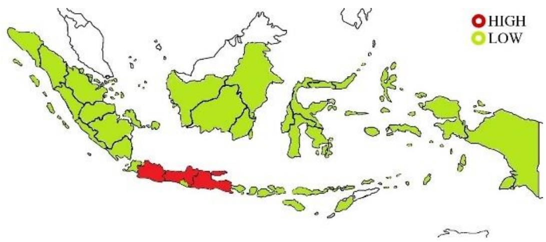


Fig. 4. Provinces clustering map in Indonesia based on livestock meat production

Figure 4 is a map of Indonesia with production centers and the availability of livestock meat. The red color on the map shows the provinces in Indonesia with high meat production. The green color on the map shows provinces in Indonesia with low meat production.

From the explanation above, it is concluded that in 2020 cluster 1 is a group of provinces with a higher total production yield than the local group in cluster 2. While cluster 2 is a group of provinces with low meat production. Provinces with high livestock meat production include West Java, Central Java and East Java. This situation is reinforced by the book Animal Business Data 2020 by Dr. Ir. Rochadi Tawaf MS et al. at agribusinessnetwork.com said that most of the highest livestock production was on Java Island.

West Java, Central Java and East Java have sufficient land available for raising livestock [24]. The people of West Java, Central Java and East Java mostly work as breeders, therefore in West Java, Central Java and East Java the production of livestock meat is high.

5. Conclusion

Based on the research and discussion described above, the following conclusions can be drawn: clustering using Fuzzy C-Means is formed into 2 clusters with cluster 1 (high) consisting of the provinces of West Java, Central Java and East Java and cluster 2 (low) consisting of Aceh, North Sumatra, West Sumatra, Riau, Jambi, South Sumatra, Bengkulu, Lampung, Bangka Belitung islands, Riau islands, Jakarta, DI Yogyakarta, Banten, Bali, NTB, NTT, West Kalimantan, East Kalimantan, Central Kalimantan, South Kalimantan, North Kalimantan, North Sulawesi, Central Sulawesi, South Sulawesi, Southeast Sulawesi, Gorontalo, West Sulawesi, Maluku, North Maluku, West Papua and Papua.

West Java, Central Java, and East Java all have enough area for livestock to be raised, and the majority of the people work as livestock breeders. As a result, these three provinces generate the most meat in Indonesia.

The Silhouette index test can be used to validate the Fuzzy C-Means clustering algorithm on livestock meat production in Indonesia in 2020. In this study, the silhouette test value was 0.95664, where the Silhouette Index value was > 0.51. This statement indicates that the grouping done is correct and appropriate.

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