COMPARISON OF FUZZY C-MEANS, FUZZY POSSIBILISTIC C-MEANS AND POSSIBILISTIC FUZZY C-MEANS ALGORITHMS ON THE DISTRIBUTION OF CONTRACEPTIVE USERS IN NTB PROVINCE

Laily Rizqi Amaliyah[1], Abdul Rahim[2*], Ayu Septiani[1]

[1]Department of Statistics, Universitas Hamzanwadi (INDONESIA)
[2]Departement Of Pharmacy, Universitas Mulawarman (INDONESIA)

**Corresponding author: rahimkhanrewa12@gmail.com*

Abstract

Fuzzy Clustering is one of the parts from purposeful cluster method for group data by similarity characteristics. Advantages from method Fuzzy Clustering compared with method cluster other could make more detailed clusters. There are several methods in Fuzzy Clustering, including Fuzzy C-Means, Fuzzy Possibilistic C-Means and Possibilistic Fuzzy C-Means. Third method the could applied in various one field-field health that is for see scatter group user contraception. Contraception is tool for prevent proclaimed pregnancy for the success of the Family program Planning (KB) in push rate growth resident. Destination from study this is for compare third method Fuzzy Clustering with see score accuracy and see results cluster best formed based on score index validity Modified Partition Coefficient (MPC). Analysis result show that method Fuzzy C-Means is the best method seen from more MPC value height in each cluster. However, if seen from score iteration and time computation, method Fuzzy Possibilistic C-Means far more effective. There are 2 optimal

clusters formed that is cluster 1 which describes spread user method contraception highest for tool contraception period length in NTB Province with amount districts reached 59. The dominating districts that is located on the island of Sumbawa. Whereas cluster 2 shows spread user tool contraception period tall, short that is It reaches 57 sub districts and is dominated by sub-districts on the island of Lombok.
Keywords: Clustering, Fuzzy Clustering, Fuzzy C-Means, Fuzzy Possibilistic C-Means, Possibilistic Fuzzy C-Means.

1 INTRODUCTION

Fuzzy clustering is one part from method target cluster for group data by similarity characteristics [1]. Advantages method this compared with method cluster other could make more detailed clusters, so that make it easy for knowing which cluster is low-very low, high-very high and so on. Fuzzy Clustering implement degrees membership in determination member ranged cluster between 0 to 1 [2]. There is a number of methods in Fuzzy Clustering, including Fuzzy C-Means (FCM), Fuzzy Possibilistic C-Means (FPCM) and Possibilistic Fuzzy C-Means (PFCM). FCM is the simplest method in Fuzzy Clustering. Whereas FPCM method is development from FCM and Possibilistic C-Means (PCM) methods. Then next FPCM method developed Becomes PFCM method.

Method analysis could be applied in various one field health that is for see spread user contraception. Contraception is tool for prevent pregnancy [3]. this program announced by the government for support Family program success Planning (KB) [4]. Based on data from the NTB BKKBN, there are 26.41% of couples Age Fertile (EFA) that is not join family planning in 2019 and increase to 26.65% in 2020. However, in 2021 it will experience drop by 1.07% to 25.58%. Plan Strategic by the NTB Province BKKBN in 2020 can lower percentage low use tool contraception with a target of 14.24% in 2022 and it is expected that in 2024 it will be down to 13.84%. A number of factor reason low number use tool contraception among them like factor economics , EFA knowledge about family planning, to factor facility

unfinished health adequate [5]. In skeleton effort countermeasures Thing, the so need is known by Specific areas that have not affordable and necessary maximized in enhancement use tool contraception for maximize the family planning program.

Study related with method clustering was carried out by Ramadhan, A., et.al., [6] with compare K-Means and FCM methods for grouping User Knowledge Modelling data. Research results show that FCM method is method best because have score validity highest. Study other carried out by Putri, GNS, et.al., [7] with compare FCM and FPCM algorithms for grouping tweets data on account Tokopedia twitter . Study this produce conclusion that algorithm best in formation cluster i.e. FCM with the highest MPC value and form 4 optimal *clusters.*

2 METHODOLOGY

2.1 Clustering

Clustering is one method multivariate purpose for group data by the characteristics it has or level resemblance [8]. Because of that's existing object in same group relatively more homogeneous (has the same characteristics) compared objects that are in different groups [9]. Based on structure, clustering divided Becomes two that is hierarchy and partition [10]. Clustering that uses draft partition there is three that is partition classic, partition Fuzzy and partition Possibilistic [11]. On partition classic, one data only will have 2 possibilities score membership i.e. 1 or 0, where only there are 2 possibilities Becomes member A or no Becomes member A. On partition Fuzzy, membership a data is declared with degrees membership located between the interval 0 to 1 [12]. Whereas for partition Possibilistic, sum score membership every data on all Cluster no must be 1.

2.2 Logica Fuzzy

Logic Fuzzy is method that was first introduced by Pradalah something the right way for map something input space to in something output space [13]. Logic Fuzzy basically is valuable logic much can define score between common situation like right and wrong, yes and no,

black and white or success and failure [10]. Logic Fuzzy have degrees membership in range 0 to 1, different with logic Boolean which only have two score namely 0 and 1 [14].

2.3 Fuzzy C-Means

Fuzzy C-Means is method development data grouping from K-Means where existence each group determined by degree membership ranges between 0 and 1 [15]. The taller score membership so the taller degrees membership, so on the contrary the more small score membership so the more small degrees membership. The following is a grouping algorithm using the FCM method:

1. Enter the data to be grouped in the form of a matrix of size nxm (n = number of data, p = attribute of each data).
2. Determine:
   a. Number of clusters (c)
   b. Weighting power (m)
   c. Maximum iterations
   d. Smallest error (ε)
   e. Initial objective function ($P_0 = 0$)
   f. Initial iteration (t=1)
3. Generating random numbers as the initial partition matrix (μ_{ik}) , namely the relative peculiarity matrix of size ixk (i = number of data, k = number *of clusters*) where the row value of each matrix is 1.
4. Calculate the *cluster center* (V_{kj})with Equation (1).

$$V_{kj} = \frac{\sum_{i=1}^{n}[(U_{ik})^{w} X_{ij}]}{\sum_{i=1}^{n}(U_{ik})^{w}} \quad (1)$$

5. Calculate the objective function (P) with the following formula:

$$P = \sum_{i=1}^{n}\sum_{k=1}^{c}\left[\left(\sum_{j=1}^{m}\left(X_{ij}\text{-}V_{kj}\right)^{w}\right)(U_{ik})^{w}\right]$$

6. Fixed the relative peculiarity matrix (μ_{ik}) in Equation (2).

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

7. Check condition stop:
   a. If $| P_t - P_{t-1} | < \varepsilon$ or t > Maxiter then stop
   b. If no : t = t+1 then repeat step 4

2.4 Fuzzy Possibilistic C-Means

Fuzzy Possibilistic C - Means (FPCM) is something algorithm development from Fuzzy C- Means (FCM) and Possibilistic C Means (PCM) [16]. Step- step analysis on the FPCM method, namely as following:

1. Enter the data (X_{ij}) to be grouped in the form of a matrix of size nxm (n = number of data, p = number of variables).
2. Determine:
   a. Number of clusters ($c \geq 2$)
   b. FCM weighting power ($w > 1$)
   c. PCM weighting power ($\eta > 1$
   d. Maximum iterations
   e. Smallest error (ε)
   f. Initial objective function ($P_0 = 0$)
   g. Initial iteration (t=1)
3. Call matrix peculiarity relatively (μ_{ik}) and the cluster center (V_{kj}) in the final result FCM method for count matrix peculiarity absolute which is in the form of a relative peculiarity matrix (t_{ik}) with Equation (3).

$$t_{ik} = \frac{\left[\sum_{j=1}^{m}\left((X_{ij}-V_{kj})^2\right)\right]^{\frac{-1}{\eta-1}}}{\sum_{i=1}^{n}\left[\sum_{j=1}^{m}\left((X_{ij}-V_{kj})^2\right)\right]^{\frac{-1}{\eta-1}}} \quad (3)$$

4. Fixed cluster center (V_{kj}) with Equation (4).

$$V_{kj} = \frac{\sum_{i=1}^{n}(\mu_{ik}{}^{w}+t_{ik}{}^{\eta})X_{ij}}{\sum_{i=1}^{n}(\mu_{ik}{}^{w}+t_{ik}{}^{\eta})} \quad (4)$$

5. Fix μ_{ik} with Equation (5).

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

6. Fix t_{ik} with Equation (6).

$$t_{ik}=\frac{\left[\sum_{j=1}^{m}\left((X_{ij}-V_{kj})^2\right)\right]^{\frac{-1}{\eta-1}}}{\sum_{i=1}^{n}\left[\sum_{j=1}^{m}\left((X_{ij}-V_{kj})^2\right)\right]^{\frac{-1}{\eta-1}}} \quad (6)$$

7. Check condition stop:
   a. If $|P_t - P_{t-1}| < \varepsilon$ or t > Maxiter then stop
   b. If no: t = t+1 then repeat step 4

2.5 Possibilistic Fuzzy C-Means

Possibilistic Fuzzy C-Means (PFCM) is method development from Fuzzy Possibilistic C-Means [17]. Development method the conducted with give degrees different interests among matrix peculiarity relatively and matrix peculiarity absolute [18]. Step- step in algorithm PFCM that is as following:

1. Enter the data (X_{ij}) to be grouped in the form of a matrix of size nxm (n = number of data, p = number of variables).
2. Determine:
   a. Number of clusters ($c \geq 2$)
   b. FCM weighting power ($w > 1$)
   c. PCM weighting power ($\eta > 1$
   d. Maximum iterations
   e. Smallest error (ε)
   f. Initial iteration (t=1)
   g. Initial objective function ($P_0 = 0$)
   h. Weighting coefficient for relative specificity $(a > 0)$
   i. Weighting coefficient for absolute uniqueness $(a > 0)$
   j. Coefficient γ(K=1)
3. Call matrix peculiarity relatively (μ_{ik}) and the cluster center (V_{kj}) in the final result FCM method for count matrix peculiarity absolute which is in the form of a relative peculiarity matrix (t_{ik}) with Equation (7).

$$t_{ik}=\left[1+\left(\frac{b.\left[\sum_{j=1}^{m}(X_{ij}-V_{kj})^2\right]}{\gamma_k}\right)^{\frac{1}{\eta-1}}\right]^{-1} \quad (7)$$

where the value γ_k can be found by Equation (8).

$$\gamma_k = K\frac{\sum_{i=1}^{n}\left[(\mu_{ik})^w\left(\sum_{j=1}^{m}(x_{ij}-v_{kj})^2\right)\right]}{\sum_{i=1}^{n}(\mu_{ik})^w} \quad (8)$$

4. Fixed *cluster center* (V_{kj}) with Equation (9).

$$V_{kj} = \frac{\sum_{i=1}^{n}(a\mu_{ik}{}^w + bt_{ik}{}^\eta)x_{ij}}{\sum_{i=1}^{n}(a\mu_{ik}{}^w + bt_{ik}{}^\eta)} \quad (9)$$

5. Repair matrix peculiarity relatively $(\mu_{ik})$and the absolute uniqueness matrix (t_{ik}) according to the formula stated in the FPCM algorithm.
6. Check condition stop:
   a. If $| P_t - P_{t-1} | < \varepsilon$ or t > Max iteration, then stop
   b. If no: t = t+1 then repeat step 4

2.6 Validity Cluster

One method for knowing the quality of the clusters formed is with see score validity clusters. The value of the cluster validity index in the fuzzy method exists two that is Partition Coefficient (PC) and Modified Partition Coefficient (MPC) [11]. MPC is index validity results repair from the PC, because on the PC the value is tend experience change. Following formula for look for MPC value as in Equation (10), where n = many studies, c = many group, U_{ik} = score membership object i-th with center group to -k.

$$MPC = 1 - \frac{C}{C-1}(1-PC(c)) \quad (10)$$

As for the formula for look for PC values in Equation (11):

$$PC = \frac{1}{n}\sum_{k=1}^{c}\sum_{i=1}^{n}U_{ik}{}^2 \quad (11)$$

3 RESULT

3.1 Application Method

3.1.1 Grouping with Fuzzy C-Means (FCM)

Table 1. *Grouping results with FCM.*

Cluster	MPC	Number of Iterations	Computing Time
2	0.4640712	49	0.15
3	0.4389218	73	0.33
4	0.3809439	179	1.18
5	0.3595105	127	1.10
6	0.3753652	121	1.16
7	0.3459356	177	2.04
8	0.3346046	179	2.28

Based on ***Table. 1,*** *we* can see that optimal *cluster* formed with use FCM algorithm that is in *cluster* 2 with highest MPC value as big as 0.5552903 with amount iteration as much as 35 and time computing 0.11 seconds.

3.1.2 Grouping with Fuzzy Possibilistic C-Means (FPCM)

Table 2. *The results of grouping with FP CM.*

Cluster	**MPC**	**Number of Iterations**	**Computing Time**
2	0.4640706	33	0.11
3	0.4388908	43	0.22
4	0.3808963	119	0.86
5	0.3595786	74	0.64
6	0.3754238	66	0.70
7	0.3460403	112	1.33
8	0.3344400	150	2.12

In ***Table. 2,*** *we* can conclude that Cluster 2 is optimal cluster formed for FPCM method. This thing seen from highest MPC value that is as big as 0.5552900 with amount iteration as much as 21 and time computing 0.07 seconds.

3.1.3 Grouping with Possibilistic Fuzzy C-Means (PFCM)

Table 3. *The results of grouping with PFCM.*

Cluster	MPC	Number of Iterations	Computing Time
2	0.4608578	49	0.17
3	0.4301043	70	0.45
4	0.3719067	210	1.38
5	0.3527553	102	0.83
6	0.3677679	118	1.18
7	0.3386125	115	1.29
8	0.3216874	164	2.11

Grouping with use PFCM method shows that optimal cluster formed i.e. 2. This seen from score MPC highest that is as big as 0.5538285 with amount iteration as many as 31 and time computing 0.11 seconds.

3.1 *Cluster* Method Comparison

3.2.1 Number of Iterations

Comparison of the number of iterations in ***Table.4.*** shows that the FPCM. method has fewer iterations than the FCM. method and PFCM on all clusters. So, it can be concluded that the FPCM. method have more iterations little compared to FCM and PFCM.

Table 4. *Comparison Amount Iteration*

Cluster	Amount Iteration		
	FCM	FPCM	PFCM
2	49	33	49
3	73	43	70
4	179	119	210
5	127	74	102
6	121	66	118
7	177	112	115
8	179	150	164

3.2.2 Computing Time

Table 5. *Computing Time Comparison*

Cluster	Amount Iteration		
	FCM	FPCM	PFCM
2	0.15	0.11	0.17
3	0.33	0.22	0.45
4	1.18	0.86	1.38
5	1.10	0.64	0.83
6	1.16	0.70	1.18
7	2.04	1.33	1.29
8	2.28	2.12	2.11

Based on ***Table. 5,*** it can be seen the comparison of the computational time for the three methods. On all clusters the FPCM method has less time than the FCM method. Meanwhile on the cluster 8 in the P FCM method have time more slightly compared to the FPCM method. Based on this, it can be concluded that the computational time of FPCM is faster than FPCM FCM and PFCM.

3.2.3 Modified Partition Coefficient (MPC)

Table 6. *Comparison MPC.*

Cluster	**MPC**		
	FCM	**FPCM**	**PFCM**
2	0.4640712	0.4640706	0.4608578
3	0.4389218	0.4388908	0.4301043
4	0.3809439	0.3808963	0.3719067
5	0.3595105	0.3595786	0.3527553
6	0.3753652	0.3754238	0.3677679
7	0.3459356	0.3460403	0.3386125
8	0.3346046	0.3344400	0.3216874

The MPC value is used to determine the best method. The higher MPC value then it shows the optimal value. In ***Table. 6,*** The MPC values in all clusters in the FCM. Method higher than the PFCM

method. Meanwhile, in clusters 5, 6 and 7 in the FPCM method, has the highest MPC value compared to the FCM method. Because of that, it can be concluded that the use of the FCM method in research this is more methods better compared to the FPCM and PFCM methods.

3.2 Cluster Result Profiling

In determining the best method, it was found that the FCM method is a better method than the FPCM and PFCM methods. So, in determining the optimal number of clusters, the results of cluster analysis using the method are used FCM. The criteria for determining the optimal cluster is by looking at the highest MPC value (***Table. 7***). Based on ***Table. 7,*** Cluster 2 has the highest MPC value with a value of 0.4640712. Then the optimal number of clusters formed is 2 clusters. The description of the characteristics of each cluster can be seen in the following profiling table:

Table 7. *MPC value.*

Cluster	MPC
2	0.4640712
3	0.4389218
4	0.3809439
5	0.3595105
6	0.3753652
7	0.3459356
8	0.3346046

Table 8. *Cluster Result Profiling.*

Cluster	Average							Multiple Members
	X1	X2	X3	X4	X5	X6	X7	
1	12.76	2.17	0.29	26.96	1.14	33.97	5.68	59
2	7.57	1.57	0.29	17.89	1.20	52.84	8.24	57

Based on ***Table. 8,*** we can see description characteristics results cluster of each variable. Spread user method contraception highest for tool contraception period length in NTB Province, namely is in cluster

1 with amount districts reached 59. The dominating districts that are located on the island of Sumbawa. Whereas cluster 2 shows spread user tool contraception period tall, short that is It reaches 57 subdistricts and is dominated by sub-districts on the island of Lombok. Following table showing results clusters on the distribution user tool contraception in NTB province:

Table 9. *Clustering Results User Contraceptives in NTB Province.*

Cluster	Regency	Member Cluster (District)
1	West Lombok	Batu Layar, Lingsar, Narmada, Labuapi, Gerung, Lembar, Sekotong
	Central Lombok	Pujut, West Praya
	East Lombok	Sukamulia, Selong, Montong Gading, Pringgasela, Suralaga, Sembalun
	Mataram City	Mataram
	KLU	Gangga, Bayan
	Sumbawa	Lunyuk, Alas, Utan, Batu Lanteh, Sumbawa, Moyo Hulu, Ropang, Lape, Plampang, Empang, Labuhan Badas, Labangka, Buer, Unter Iwes, Moyo Utara, Maronge, Tarano, Lopok, Lenangguar, Lantung
	Dompu	Hu'u, Kilo, Pekat, Manggalewa, Pajo
	Bima	Monta, Wawo, Sape, Langgudu, Tambora, Parado, Lambitu, Palibelo
	West Sumbawa	Seteluk, Sekongkang, Brang Rea
	Bima City	Rasana E-Barat, East Rasana E, Asakota, Raba, Mpunda
2	West Lombok	Gunungsari, Kediri, Kuripan

Cluster	Regency	Member Cluster (District)
	Central Lombok	Praya, Jonggat, Batukliang, East Praya, Janapria, Pringgarata, Kopang, Middle Praya, Southwest Praya, North Batukliang
	East Lombok	Keruak, Sakra, Terara, Sikur, Masbagik, Pringgabaya, Aikmel, Sambelia, Wanasaba, Suela, Labuhan Haji, East Sakra, West Sakra, Jerowaru
	Kota Mataram	Ampenan, Cakranegara, Sekarbela, Selaparang, Sandubaya
	KLU	Tanjung, Kayangan, Pemenang
	Sumbawa	Moyo Hilir, Alas Barat, Rhee, Orong Telu
	Dompu	Dompu, Kempo, Woja
	Bima	Bolo, Woha, Belo, Wera, Donggo, Sanggar, Ambalawi, Lambu, Madapangga, Soromandi
	West Sumbawa	Jereweh, Taliwang, Poto Tano, Brang Ene, Maluk

Table. 9 shows cluster results for every sub district in the province of NTB for percentage user tool contraception based on PUS. Cluster 1 shows height spread user tool contraception period length in 59 districts. As for the districts the spread over two island that is as much as 18 sub-districts on the island of Lombok and 41 sub -districts on the island of Sumbawa. That thing shows that use tool contraception period longer on the island of Sumbawa more dominated compared tool contraception period short. Whereas cluster 2 describes spread percentage use tool contraception period short. The high school consists of 57 subdistricts spread over 5 districts on the island of Lombok as many as 35 sub districts and 4 districts on the island of Sumbawa as many as 22 districts. This thing shows that use tool contraception period short dominated by sub-districts on the island of Lombok.

3 CONCLUSION

Application third method i.e. FCM, FPCM and PFCM produce analysis that optimal cluster formed as much as 2. Based on the comparison of the number iteration and time computing, FPCM method is more excel. This is because the FPCM method has more iterations and less computation time than the FCM and PFCM methods. Meanwhile, when viewed from the MPC value, the FCM method is better because the MPC value in clusters 2 to 8 shows a higher value than the PFCM method. While in the FPCM method there are 2 clusters that have a high value compared to FCM, namely clusters 5 and 6. Analysis result show that spread user method contraception highest for tool contraception period length in NTB Province, namely is in cluster 1 with amount districts reached 59. The dominating districts that is located on the island of Sumbawa. Whereas cluster 2 shows spread user tool contraception period tall, short that is It reaches 57 sub districts and is dominated by sub-districts on the island of Lombok.

REFERENCES

[1] G. R. Apsari, M. S. Pradana, and N. E. Chandra, "Implementasi Fuzzy C-Means dan Possibilistik C-Means Pada Data Performance Mahasiswa," *Unisda J. Math. Comput. Sci.*, vol. 6, no. 2, pp. 39–48, 2020, doi: 10.52166/ujmc.v6i2.2392.

[2] C. L. Chowdhary, M. Mittal, P. Kumaresan, P. A. Pattanaik, and Z. Marszalek, "An efficient segmentation and classification system in medical images using intuitionist possibilistic fuzzy C-mean clustering and fuzzy SVM algorithm," *Sensors (Switzerland)*, vol. 20, no. 14, pp. 1–20, 2020, doi: 10.3390/s20143903.

[3] S. Hanada and T. S. Yanti, "Penggunaan Analisis Cluster dalam Pengelompokan Kecamatan di Kabupaten Karawang Berdasarkan Metode Kontrasepsi Peserta KB Aktif," *Pros. Stat.*, vol. 7, no. 1, pp. 1–8, 2021.

[4] M. Majid, "Pengembangan Metode Penyuluhan Meningkatkan Pemakaian Alat Kontrasepsi," *Media Kesehat. Masy. Indones.*, vol. 13, no. 1, p. 91, 2017, doi: 10.30597/mkmi.v13i1.1585.

[5] A. N. Huda, L. Widagdo, and B. Widjanarko, "Faktor-Faktor Yang Berhubungan Dengan Perilaku Penggunaan Alat Kontrasepsi Pada Wanita Usia Subur Di Puskesmas Jombang-Kota," *J. Kesehat. Masy.*, vol. 4, no. 1, 2016.

[6] A. Ramadhan, Z. Efendi, and Mustakim, "Perbandingan K-Means dan Fuzzy C-Means untuk Pengelompokan Data User Knowledge Modeling," *Semin. Nas. Teknol. Informasi, Komun. dan Ind. 9*, pp. 219–226, 2017.

[7] G. N. S. Putri, D. Ispriyanti, and T. Widiharih, "Implementasi Algoritma Fuzzy C-Means Dan Fuzzy Possibilistics C-Means Untuk Klasterisasi Data Tweets Pada Akun Twitter Tokopedia," *J. Gaussian*, vol. 11, no. 1, pp. 86–98, 2022, doi: 10.14710/j.gauss.v11i1.33996.

[8] Ediyanto, N. Mara, and N. Satyahadewi, "Pengklasifikasian Karakteristik Dengan Metode K-Means Cluster Analysis," *Bul. Ilm. Mat. Stat. dan Ter.*, vol. 02, no. 2, pp. 133–136, 2013.

[9] B. M. Metisen and H. L. Sari, "Analisis Clustering Menggunakan Metode K-Means Dalam Pengelompokkan Penjualan Produk Pada Swalayan Fadhila," *J. Media Infotama*, vol. 11, no. 2, pp. 110–118, 2015.

[10] N. Irabawati, S. Wahyuningsih, and R. R. Syoer, "Perbandingan Metode C-Means dan Fuzzy C-Means Dalam PengelompokkanWilayah Desa/Kelurahan di Kabupaten Kutai Kartanegara," *J. Eksponensial*, vol. 7, no. 1, pp. 67–76, 2016.

[11] B. N. Haqiqi and R. Kurniawan, "Analisis Perbandingan Metode Fuzzy C-Means Dan Subtractive Fuzzy C-Means," *Media Stat.*, vol. 8, no. 2, pp. 59–67, 2015, doi: 10.14710/medstat.8.2.59-67.

[12] D. L. Rahakbauw, V. Y. I. Ilwaru, and M. H. Hahury, "Implementasi Fuzzy C-Means Clustering Dalam Penentuan Beasiswa," *J. Ilmu Mat. dan Terap.*, vol. 11, no. 1, pp. 1–12, 2017.

[13] H. S. Firdaus, A. L. Nugraha, B. Sasmito, M. Awaluddin, and C. A. Nanda, "Perbandingan Metode Fuzzy C-Means Dan K-Means Untuk Pemetaan Daerah Rawan Kriminalitas," *Elipsoida*, vol. 04, no. 01, pp. 58–64, 2021.

[14] S. Putriana, E. Ernawati, and D. Andreswari, "Clustering Data Titik Gempa Dengan Metode Fuzzy Possibilistic C-Means (Studi Kasus: Titik Gempa Pulau Sumatera Tahun 2013- 2018)," *J. Rekursif*, vol. 9, no. 1, 2021, doi: 10.33369/rekursif.v9i1.15898.

[15] M. A. B. Siddique, R. B. Arif, M. M. R. Khan, and Z. Ashrafi, "Implementation of Fuzzy C-Means and Possibilistic C-Means Clustering Algorithms, Cluster Tendency Analysis and Cluster Validation," *ArXive e-Journal*, 2018, [Online]. Available: http://arxiv.org/abs/1809.08417

[16] T. Thilagaraj and N. Sengottaiyan, "Implementation of fuzzy C-means and fuzzy possibilistic C-means algorithms to find the low performers using R-tool," *Int. J. Sci. Technol. Res.*, vol. 8, no. 8, pp. 1697–1701, 2019.

[17] N. R. Pal, K. Pal, J. M. Keller, and J. C. Bezdek, "A possibilistic fuzzy c-means clustering algorithm," *IEEE Trans. Fuzzy Syst.*, vol. 13, no. 4, pp. 517–530, 2005, doi: 10.1109/TFUZZ.2004.840099.

[18] B. O. Magana, R. Ruelas, M. A. C. Nakamura, and D. Andina, "An Improvement To The Possibilistic Fuzzy C-Means Clustering Algorithm," *World Autom. Congr.*, 2006.