JTAM (Jurnal Teori dan Aplikasi Matematika)
http://journal.ummat.ac.id/index.php/jtam
p-ISSN 2597-7512 | e-ISSN 2614-1175
Vol. 9, No. 3, July 2025, pp. 733-751

Spatial Fuzzy Clustering Algorithm for Optimizing Inclusive Da'wah Distribution Patterns

Abdul Karim[1,2]*, Adeni[1], Agus Riyadi[1], Achmad Yafik Mursyid[3]
[1]Universitas Islam Negeri Walisongo, Indonesia
[2]Universitas Airlangga, Indonesia
[3]University of Malaya, Malaysia
abdulkarim@walisongo.ac.id

Article History:
Received : 16-04-2025
Revised : 28-05-2025
Accepted : 02-06-2025
Online : 01-07-2025

Keywords:
Spatial analysis;
Spatial fuzzy clustering;
Fuzzy geographically weighted clustering;
Inclusive da'wah;
Mapping da'wah.

ABSTRACT

This article aims to identify and analyse the potential for inclusive da'wah in Central Java Province, Indonesia, by focusing on three fundamental aspects that determine the success of the da'wah process: the subject, the object, and the environment of the da'wah. This research applies an empirical approach through a series of spatial clustering analyses using the fuzzy geographically weighted clustering (FGWC) method to determine the optimum number of clusters in mapping the potential for da'wah. FGWC is a spatial analysis method that combines the concept of fuzzy clustering with a geographically weighted approach, allowing for more flexible and contextual identification of distribution patterns based on location. This method was chosen for its ability to handle uncertainty in spatial data as well as considering geographical variations in clustering. The data used in this study came from the Ministry of Religious Affairs of the Republic of Indonesia and the Central Statistics Agency (BPS) of Central Java Province, covering demographic, social, and religious data from 35 districts/cities in Central Java. The results of the FGWC analysis show that the optimum number of clusters is two, with districts/cities in the second cluster identified as having higher da'wah potential. This is evidenced by six high-value variables in the second cluster, while the first cluster has only one high-value variable. These findings have significant implications for inclusive da'wah strategies in Central Java. These results can be used as a strategy for mapping priority da'wah areas, allocating effective resources, and developing a more contextualised da'wah approach according to the characteristics of each cluster. This research's originality lies in applying the FGWC method in the context of da'wah mapping. This article is the first to combine spatial analysis with a study of the potential for inclusive da'wah, thus contributing to developing an interdisciplinary approach in the study of contemporary Islam in Indonesia.

https://doi.org/10.31764/jtam.v9i3.30599

A. INTRODUCTION

Inclusive da'wah is an approach to spreading Islamic teachings that prioritises tolerance, dialogue, and respect for diversity (Suherman & Rustandi, 2023). This aligns with Islam's universal values as rahmatan lil 'alamin (grace for all creation)(Abdul et al., 2024; Doya, 2020). In Indonesia's multicultural and multi-religious society (Japar et al., 2019; Muh Aditya Ibrahim et al., 2023; Riyadi & Karim, 2023), inclusive da'wah is highly relevant for maintaining social harmony and strengthening community cohesion amid the challenges of pluralism (Riyadi et al., 2024; Wawaysadhya et al., 2022; Zamakhsyari & Majene, 2020). Central Java province, with

its socio-cultural diversity and complex demographic composition (Amin, 2012; Setyoningrum et al., 2021), is an ideal laboratory for studying the effectiveness and strategies of inclusive da'wah in the contemporary Indonesian context. The success of da'wah is not only determined by the quality of the material delivered but also depends heavily on an understanding of the characteristics of the da'wah area, including the aspects of the subject (da'i), object (mad'u) and da'wah environment (Hibrizi, 2024; Rosmalina & Khaerunnisa, 2021). A systematic and comprehensive approach is needed to identify and map the potential for da'wah in each region to deliver the message effectively and on target.

The measurement of the potential for da'wah is a multidimensional measurement that uses several indicators (Karim et al., 2021). Therefore, one of the analyses that can be used is cluster analysis. Cluster analysis is expected to determine the characteristics of a group of data (Astuti & Untari, 2017), making it easier to analyse the potential da'wah based on the needs of each cluster. However, although cluster analysis can group data based on indicators, it cannot produce an optimum cluster if the data has a geographical structure (Liao & Peng, 2012).

The significance of this research lies in the urgency of developing a more measurable, systematic, and data-based da'wah strategy in dealing with the socio-religious complexity of contemporary Indonesia. Mapping the potential for da'wah is very important given the increasing challenges of da'wah in the digital and global era, including radicalism, intolerance, and identity-based conflicts that threaten social harmony (asmar & Perdana, 2024). The province of Central Java, with 35 districts/cities with diverse socio-cultural and demographic characteristics, requires different approaches to da'wah according to the local context of each region. Inclusive da'wah efforts can be ineffective or even counterproductive without a deep understanding of the characteristics of the area of da'wah. Through a spatial analysis approach, this study offers a new analysis of the study of da'wah, which has tended to be normative and has paid less attention to empirical and contextual aspects. Therefore, it is hoped that the results of this study can bridge the gap between the theory and practice of da'wah in the field (Kadri, 2022; Mahmuddin et al., 2018; Nurjanah, 2024).

Previous researchers have conducted many studies on inclusive da'wah. However, most still focus on normative, theological, and philosophical aspects, while empirical and methodological aspects have not been developed much. Khasanah (2022) emphasise the importance of contextualising da'wah by paying attention to the socio-cultural conditions of the target community but have not offered an empirical method for mapping the characteristics of the da'wah area. Meanwhile, Marfu'ah (2018) has studied da'wah strategies in a multicultural society, but has not integrated spatial analysis into his study. Karim et al. (2021) research on mapping the potential for da'wah in Semarang City has applied a clustering analysis but still uses conventional statistical methods that pay less attention to spatial aspects. On the other hand, the use of the FGWC method in spatial analysis has been widely developed in various fields, such as regional economics (Nasution & Siregar, 2022), demography (Grekousis, 2021a), and regional planning (Sumargo et al., 2024), but its application in da'wah studies is still very limited and has not been explored much.

The research gap that is the focus of this article is the lack of integration between spatial approaches, especially the FGWC method, and the study of the potential for inclusive da'wah. Although several previous studies have examined inclusive da'wah from various perspectives,

none have specifically applied spatial clustering analysis to map the potential for da'wah based on regional characteristics. Using the FGWC method in this study offers an advantage because it can integrate geographical aspects in the grouping analysis to produce a more accurate and contextual typology of the da'wah area. This methodological gap is becoming increasingly relevant given the growing complexity of the challenges of da'wah in the contemporary era, which requires a more systematic and data-based approach.

The novelty of this research lies in applying the FGWC method in mapping the potential for inclusive da'wah, which is the first approach to combine spatial analysis with the study of da'wah strategies. By integrating demographic, social, and religious data from 35 districts/cities in Central Java, this research produces a typology of da'wah areas that can form the basis for developing more contextual and effective da'wah strategies. The interdisciplinary approach combining quantitative methods (FGWC) with Islamic da'wah studies is expected to contribute to contemporary Islamic studies in Indonesia significantly. In addition, the results of the mapping in this study not only contribute to scientific development but have practical implications for da'wah practitioners, policymakers, and da'wah institutions in designing da'wah programmes that are more responsive to the needs and characteristics of local communities.

This study aims to identify and analyse the potential for inclusive da'wah in Central Java Province with a focus on three fundamental aspects: the subject of da'wah (da'i), the object of da'wah (mad'u), and the environment of da'wah. Through spatial clustering analysis, this study attempts to map districts/cities in Central Java based on their da'wah potential to produce a typology of da'wah areas that can form the basis for developing a more contextualised da'wah strategy. This study also aims to apply the fuzzy geographically weighted clustering (FGWC) method in the context of da'wah mapping to produce more accurate regional groupings based on spatial and non-spatial characteristics. By integrating demographic, social, and religious data, this study seeks to provide a comprehensive picture of the da'wah landscape in Central Java. The results of this mapping are expected to provide theoretical and practical contributions to developing an inclusive da'wah that is responsive to the needs and characteristics of local communities.

B. METHODS

1. Data

This type of research is quantitative research, which focuses on collecting and analyzing numerical data to measure the potential of da'wah based on various indicators. The data used in this study are secondary data from the Ministry of Religion of the Republic of Indonesia and the Central Statistics Agency (BPS) of Central Java Province. The observation unit in this research is the Regency and City in Central Java Province. Determining the variables to measure the potential of da'wah uses the da'wah map definition from the Indonesian Ulama Council (Zuhdi et al., 2017) and (Karim et al., 2021), in which the da'wah map is a systematic and detailed description of subjects, objects, and the environment in regional units. Based on this definition, three things are determining the potential of da'wah. First, the subject consists of students (prospective preachers) and *Kyai*. Second, the objects consist of Muslim residents and

non-Muslim residents. Third, the environment consists of Islamic boarding schools (*pesantren*), mosques, and population density. The operational variable definitions are as follows in Table 1.

Table 1. Definition of Variables

No.	Variable	Definition	Analysis Unit	Data Source
1	*Santri* (X1)	Number of students (da'i candidates) for each district/city in Central Java Province	Person	Ministry of Religion
2	*Kyai* (X2)	Number of *Kyai* for each district/city in Central Java Province	Person	Ministry of Religion
3	Muslims Population (X3)	Number of Muslim population for each district/city in Central Java Province	Person	BPS-Statistics Central Java Province
4	Non-Muslim Population (X4)	Number of non-Muslim population for each district/city in Central Java Province	Person	BPS-Statistics Central Java Province
5	Pesantren (X5)	Number of Pesantren for each district/city in Central Java Province	Unit	Ministry of Religion
6	Mosques (X6)	A large number of mosques, prayer rooms for each district/town in Central Java province	Unit	BPS-Statistics Central Java Province
7	Density (X7)	Population density refers to the average population per 1 km^2.	Population/km^2	BPS-Statistics Central Java Province

2. Fuzzy Geographically Weighted Clustering (FGWC)

Fuzzy Geographically Weighted Clustering (FGWC) is a spatial clustering method that combines fuzzy logic concepts with geographic location-based analysis (Hasan et al., 2023; Wijayanto et al., 2016). It aims to capture spatial variations in cluster patterns by allowing each data point to have different degrees of membership to multiple clusters, rather than a single cluster as in traditional clustering methods. In FGWC, each data point is assigned a fuzzy membership value that indicates how strongly it is associated with certain clusters, based on its spatial proximity to other data points (Grekousis, 2021b). Mathematically, the FGWC method can be explained through two main components, namely Geographically Weighted Clustering (GWC) and fuzzy logic. To begin with, the geographically-based clustering model, GWC, can be expressed in the form of the following equation:

$$d_{i,j} = |x_i - x_j| \cdot w_{i,j} \tag{1}$$

where $\boldsymbol{d_{i,j}}$ is the geographical distance between two data points $\boldsymbol{x_i}$ and $\boldsymbol{x_j}$, and $\boldsymbol{w_{i,j}}$ is a spatial weight that calculates the effect of geographical proximity between data points. The weights $\boldsymbol{w_{i,j}}$ are usually calculated using a geographic kernel function, such as a Gaussian or an inverse distance-based kernel, which gives higher weights to spatially closer points.

Furthermore, in the fuzzy framework, the membership of each data point to a particular cluster is calculated using a fuzzy membership function $\boldsymbol{\mu_{i,k}}$, which describes the degree of

membership of the data point $\boldsymbol{x_i}$ to the cluster $\boldsymbol{k}$. This membership function fulfils the properties of fuzzy logic, where:

$$0 \leq \mu_{i,k} \leq 1 \tag{2}$$

and the sum of all fuzzy memberships for each data point is 1, that is:

$$\sum_{k=1}^{K} \mu_{i,k} = 1 \tag{3}$$

where $\boldsymbol{K}$ is the number of clusters. Fuzzy memberships are calculated using an optimisation method to minimise an objective function that combines clustering error and spatial weights. Mathematically, the FGWC objective function can be written as follows:

$$J = \sum_{i=1}^{N} \sum_{k=1}^{K} \mu_{i,k}^{m} | x_i - c_k|^2 \cdot w_{i,k} \tag{4}$$

where $\boldsymbol{N}$ is the number of data points, $\boldsymbol{c_k}$ is the cluster centre $\boldsymbol{k}$, and $\boldsymbol{m}$ is a weighting parameter (usually $\boldsymbol{m} > \boldsymbol{1}$) that controls the degree of fuzziness in cluster assignment. This objective function aims to minimise the squared error between the data points and the cluster centres, taking into account the spatial influence through the weights $\boldsymbol{w_{i,k}}$. The data analysis method used is Fuzzy Geographically Weighted Clustering (FGWC) to group districts/cities based on the potential of da'wah to get the optimum number of clusters, then based on the optimum cluster, mapping of the potential of da'wah for each variable is carried out. The following are the analysis stages (Hasan et al., 2023):

a. Looking for the optimum number of clusters by considering the objective function value and validity index.
b. Mapping the potential of da'wah in Central Java with the optimum number of clusters.

After conducting the FGWC analysis and the da'wah potential in each mapping cluster is discovered, then we carry out an analysis of the da'wah strategic approach to find the right da'wah model in the context of the potential of da'wah differences in society. This part is important to do considering that the da'wah areas are inseparable from one another. Furthermore, the relationship between da'wah regions, in turn, shows Islam as an inclusive religion that is not only intended for one particular class of society but all people in any region.

3. Validity Index

In fuzzy clustering, a member can be a member of several clusters at once, depending on the degree of membership (Dahiya et al., 2021; Ferraro, 2024; Guo et al., 2020). The clustering process always seeks the best solution for the defined parameters. However, in some cases some clusters do not match the data. To determine the optimum number of clusters, it is necessary to measure the validity index (Bharill & Tiwari, 2014).

a. Partition Coefficient (PC)
   Partition Coefficient (PC) measures how data is divided into homogeneous groups. It is used to assess the quality of partitioning in fuzzy clustering, where objects can belong to

more than one cluster with different degrees of membership (Eustáquio & Nogueira, 2020).

$$PC(c) = \frac{1}{N}\sum_{i=1}^{c}\sum_{j=1}^{N}\left(\mu_{ij}{}^{2}\right) \tag{5}$$

where c is the number of clusters, N is the number of data, and μ_{ij} is the membership value of the j-th data in the i-th cluster. Partition Coefficient PC(c) describes how well the data is distributed in the cth cluster. The membership valueμ_{ij} indicates how much the jth data is connected to the i-th cluster. In this formula, μ_{ij}^{2} is used to emphasize greater membership, which means objects with stronger membership in a cluster will contribute more to the value of this index. The PC(c) value is calculated by taking the average of all the data, which gives an idea of the extent to which the data is homogeneously divided into clusters. A higher index value indicates that the data in the cth cluster is more clearly separated, with more consistent cluster members.

The most optimal cluster is determined based on the largest PC value in measuring the validity index using the PC index. According to (Gowda et al., 2024; Zeng et al., 2025) the PC index used to measure the number of overlapping clusters is transformed into a decreasing function that can adjust the fuzziness value automatically. Then, the rate of decrease in the PC index will be calculated, and the difference between successive decreases in the PC index is defined as the maximum PC index, which is used to indicate the optimal number of clusters. The higher the PC value, the better the partitioning (in the context of fuzzy clustering). The PC value ranges between 0 and 1, where a higher value indicates that objects are better separated in clusters with more consistent membership degrees (Doan & Nguyen, 2018).

b. Classification Entropy (CE)

Classification Entropy (CE) is used to measure uncertainty in object classification. In the context of fuzzy clustering, CE measures how dispersed an object's membership in various clusters is. The higher the entropy, the more uncertain or "messy" the object's membership in various clusters (Kanzawa, 2020; Mahamadou et al., 2020; Suzuki & Kanzawa, 2025). Mathematically, Classification Entropy (CE) is defined as:

$$CE(c) = \frac{1}{N}\sum_{i=1}^{c}\sum_{j=1}^{N}\mu_{ij}log\left(\mu_{ij}\right) \tag{6}$$

where c is the number of clusters formed in the clustering result, and N is the total number of clustered data or objects. The notation μ_{ij} refers to the degree of membership of the jth data in the i-th cluster, which indicates how much attachment or membership the data has to a particular cluster. The CE value for the cth cluster, CE(c), is calculated by summing up the entropy contributions of all the data in the cluster. The entropy value for each data is calculated as $\mu_{ij}\log\left(\mu_{ij}\right)$, where the logarithm is used to measure how much uncertainty or confusion is associated with the data's membership in the cluster. A lower CE value indicates that the data is more clearly clustered in the cluster, while a

higher CE value indicates greater uncertainty in the data's cluster membership. The optimal cluster is determined based on the smallest CE value, unlike the PC index. The CE index evaluates the randomness of the data in the cluster whose value is in the range [0,1] so that if the value gets smaller, closer to 0, the cluster quality improves (Carbone & Ponta, 2022; Koltcov et al., 2020; Popkov et al., 2022).

c. Xie and Beni's Index (XB)

Xie and Beni's Index (XB) combines cluster separation error with cluster density to evaluate clustering quality. This index provides information on how well the cluster is formed based on its proximity to the cluster center point and data distribution within the cluster. Xie and Beni's index aims to calculate the ratio of total within-group variation and group separation (Singh et al., 2017; Tavakkol et al., 2022). Mathematically, Xie and Beni's Index (XB) is defined as:

$$XB(c) = \frac{\sum_{i=1}^{c}\sum_{k=1}^{N}(u_{ik})^{m}\|x_k - v_i\|^2}{N min_{i,k}\|x_k - v_i\|^2} \quad (7)$$

where N is the number of objects in the research dataset, c is the number of clusters formed, u_{ik} is the degree of membership of the i-th data in the kth cluster, and m is a fuzziness parameter that measures the level of uncertainty or vagueness in the clustering, with $m > 1$, v_i is the cluster center for object i, x_k is the data point in the k-th cluster, i.e. the center of that cluster. The element u_{ik}^{m} describes the extent to which object i belongs to cluster k, considering the fuzziness level. At the same time, $|x_k - v_i|^2$ measures the distance between the data point x_k and the cluster centre v_i . This XB value is used to assess the extent to which the formed clusters are separated and how dense the clusters are. The smaller the XB value, the better the quality of the resulting clustering, as this indicates that the objects in the cluster are more well-grouped while the distance between clusters is larger (Muranishi et al., 2014; Tomašev & Radovanović, 2016).

C. RESULT AND DISCUSSION

1. Result

Based on Table 2, it can be seen that the maximum objective function is located in two clusters where each cluster has a different number of memberships and centroid values. Furthermore, to analyse the characteristics of da'wah potential, it is necessary to analyse the selection of optimal clusters using the validity index.

Table 2. Objective function

Cluster	Objective Function
2	3086683000000
3	1844838000000
4	1232504000000
5	952897168428

The validity index has the aim of knowing the most optimal number of clusters as the best solution for the parameters defined so as to facilitate the analysis of the characteristics of the dakwah map indicators. In this study uses four validity indexes that have been defined by Kurniawan & Haqiqi (2015) and Hadi (2017) namely partition coefficient, classification entropy, xie and beni's index, and separation index. The results of the validity index analysis are as Table 3.

Table 3. Validity index

Number of Clusters	Validity Index			
	PC	CE	S	XB
2	0.562	0.628	0.696	0.696
3	0.464	0.89	0.721	0.721
4	0.374	1.144	1.125	1.125
5	0.321	1.341	2.781	2.781

Table 3 shows the results of the analysis using the validity index, based on the results of the optimum cluster selection using four validity indexes, the optimum clustering quality lies in the number of two clusters because it produces the largest PC value, and has the smallest values for CE, S, and XB respectively. Visualization of clustering results of da'wah potential, as shown in Figure 1.

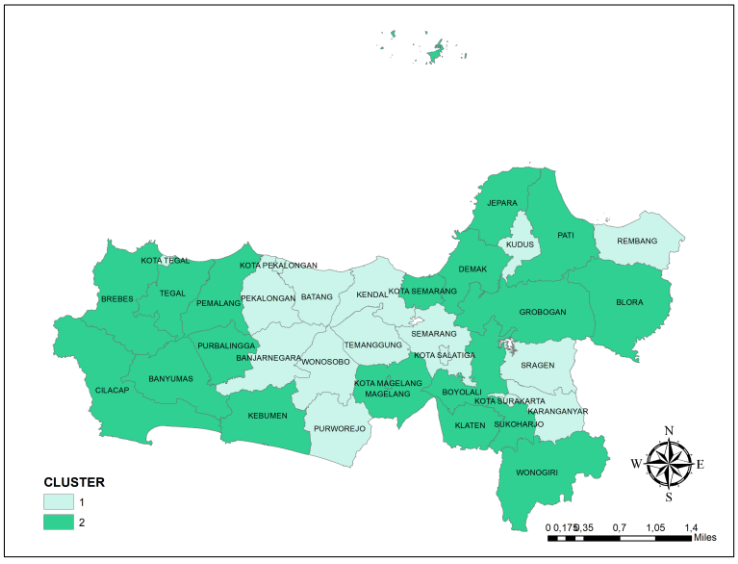

Figure 1. Visualisation of clustering results of da'wah potential

The spatial distribution of clustering results with a number of clusters of 2 is illustrated in Figure 1, with a light green map showing districts/cities that fall into cluster 1 and dark green showing districts/cities that fall into cluster 2. In addition, the clustering results in Figure 1, members of each cluster tend to cluster as in the first cluster tends to cluster in districts/cities in the central part of Central Java province. Meanwhile, the second cluster tends to cluster in regencies/cities in the western and eastern parts of Central Java province. Thus, the

distribution of clustering results shows that some clusters have geographically close members. More complete results of the above map illustration can be seen in Table 4.

Table 4. Clustering Results of Dakwah Potential

No.	Cluster 1	No.	Cluster 2
1	Banjarnegara	1	Cilacap
2	Purworejo	2	Banyumas
3	Wonosobo	3	Purbalingga
4	Karanganyar	4	Kebumen
5	Sragen	5	Magelang
6	Rembang	6	Boyolali
7	Holy	7	Klaten
8	Semarang	8	Sukoharjo
9	Temanggung	9	Wonogiri
10	Kendal	10	Grobogan
11	Trunk	11	Blora
12	Pekalongan	12	Starch
13	Surakarta City	13	Jepara
14	Salatiga City	14	Demak
15	Pekalongan City	15	Pemalang
15	Tegal City	15	Tegal
		16	Brebes
		17	Magelang City
		18	Semarang City

Based on Table 4, it can be seen that the number of regions included in cluster 2 is more than cluster 1, where cluster 1 consists of 15 regions and cluster 2 consists of 18 regions. Furthermore, Table 5 shows that the average variable in the first cluster has one high value variable, while in the second cluster there are 6 high value variables. Therefore, the regions included in the second cluster have high da'wah potential.

Table 5. Average by indicator of clustering results

Cluster	X1	X2	X3	X4	X5	X6	X7
1	91,812	11304,562	897,625	704511,312	27970	2690,562	2495,687
2	122	14073,105	1866,842	1283610,105	42460,789	4234,789	1654,947
Global	108,2	12807,485	1423,771	1018879,229	35836,428	3528,857	2039,285

Based on the results of the FGWC analysis in the previous section, it was found that the optimum number of clusters was two clusters. Thus, this section will show the spatial distribution for each indicator that measures the potential of da'wah as many as two clusters. The distribution of the number of pesantren in Central Java Province is shown in Figure 2. In the figure, it appears that the darker the colour of the location, the more the number of pesantren in the region. It can be seen that the regions with the largest number of pesantren range from 128 to 286, while the regions with the smallest number of pesantren range from 8 to 127. Magelang, Cilacap, Grobogan, Banyumas, Temanggung, Semarang City, Pemalang, Semarang, Jepara, Pati, Wonosobo, and Sragen are the regions of the second cluster that have a large number of pesantren.

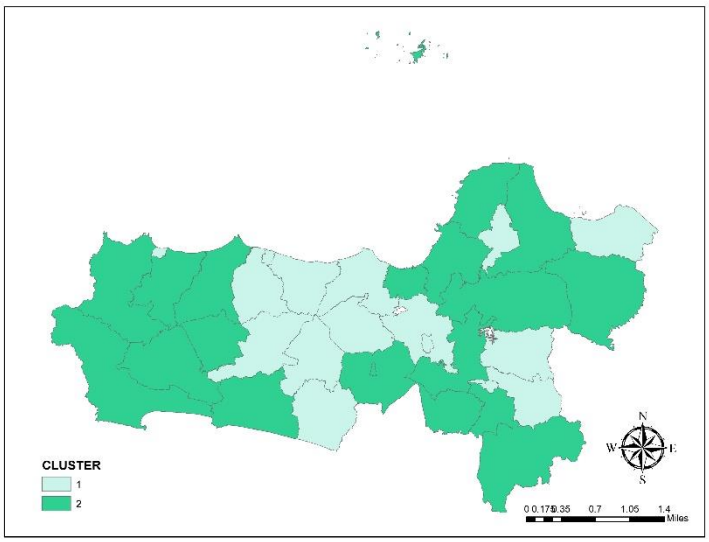

Figure 2. Spatial distribution of the number of pesantren in Central Java province

The distribution of the number of *santri* in Central Java Province is shown in Figure 3. In the figure, it appears that the darker the colour of the location, the more the number of students in the region. It can be seen that the region with the highest number of *santri* ranges from 11,991 to 38,729, while the region with the lowest number of *santri* ranges from 714 to 11,990. Magelang, Pemalang, Pati, Grobogan, Temanggung, Brebes, Jepara, Sragen, Rembang, Wonosobo, Kendal, Cilacap, Banyumas, Tegal, Demak, Purworejo, Kudus, and Banjarnegara are the second cluster regions that have a large number of students.

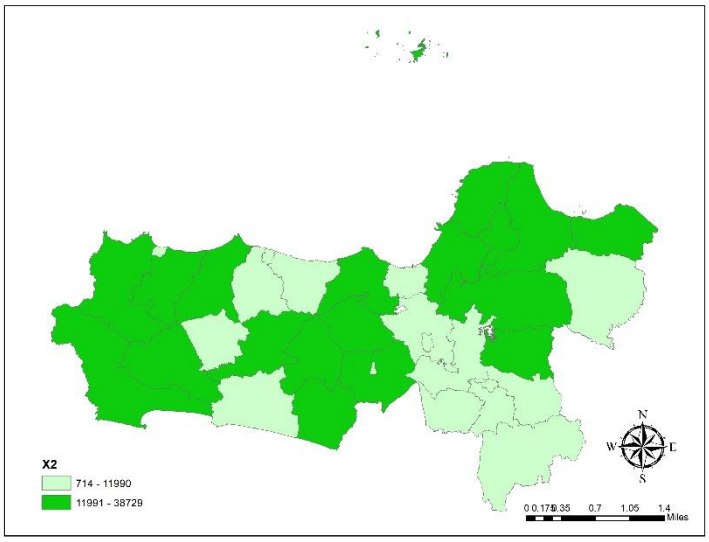

Figure 3. Spatial distribution of the number of *santri* in Central Java province

The distribution of the number of *kyais* in Central Java Province is shown in Figure 4. In the figure it appears that the darker the colour of the location, the more the number of *kyai* in the region. It can be seen that the regions with the highest number of *kyais* range from 49 to 3,691, while the regions with the lowest number of *kyais* range from 3,692 to 10,132. Grobogan and Demak are the second cluster regions that have a large number of *kyais*.

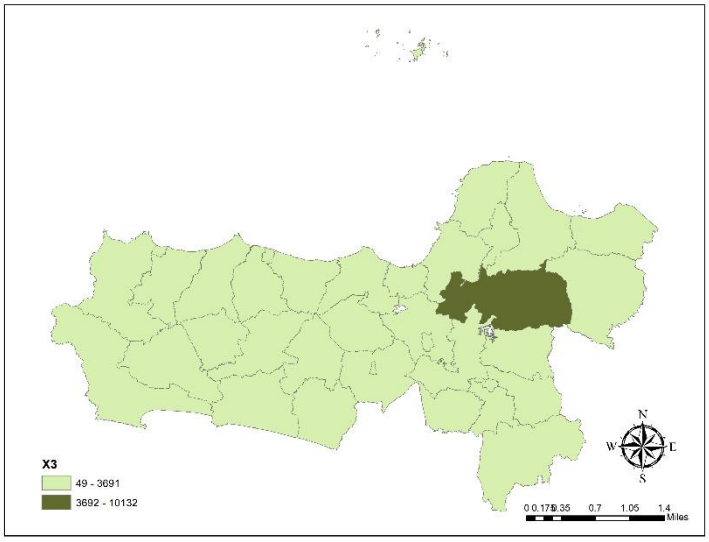

Figure 4. Spatial distribution of the number of *kyais* in Central Java province

The distribution of Muslim population in Central Java Province is shown in Figure 5. The figure shows that the darker the colour of the location, the more Muslim population in the region. It can be seen that the region with the most Muslim population ranges from 111,878 to 1,044,653, while the region with the least Muslim population ranges from 1,044,645 to 1,937,772. Brebes, Cilacap, Banyumas, Tegal, Pemalang, Grobogan, Klaten, Kebumen, Semarang City, Sukoharjo, Blora, Magelang, Pati, Demak, Jepara, and Wonogiri are the regions in the second cluster that have a large Muslim population.

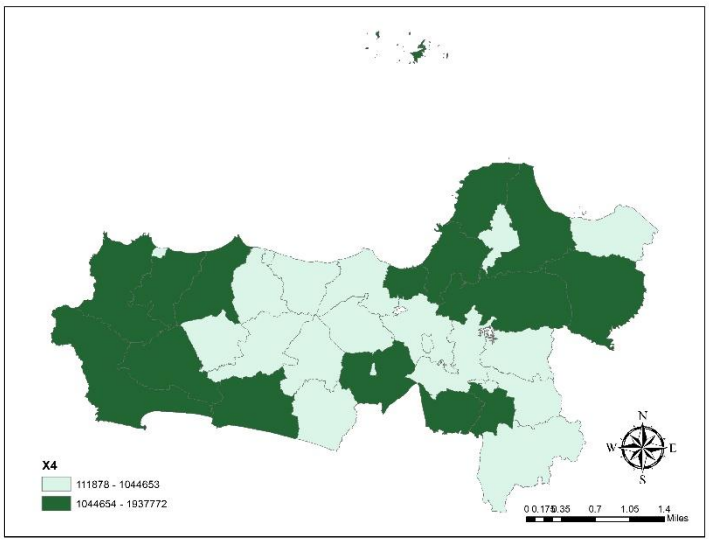

Figure 5. Spatial distribution of Muslim population in Central Java province

The distribution of non-Muslim population in Central Java Province is shown in Figure 6. The figure shows that the darker the colour, the more non-Muslim population in the region. It can be seen that the region with the highest number of non-Muslim population ranges from 3,730 to 77,940, while the region with the lowest number of non-Muslim population ranges from 77,941 to 294,687. Semarang City, Surakarta City, and Klaten City are the second cluster regions that have a large number of non-Muslim residents.

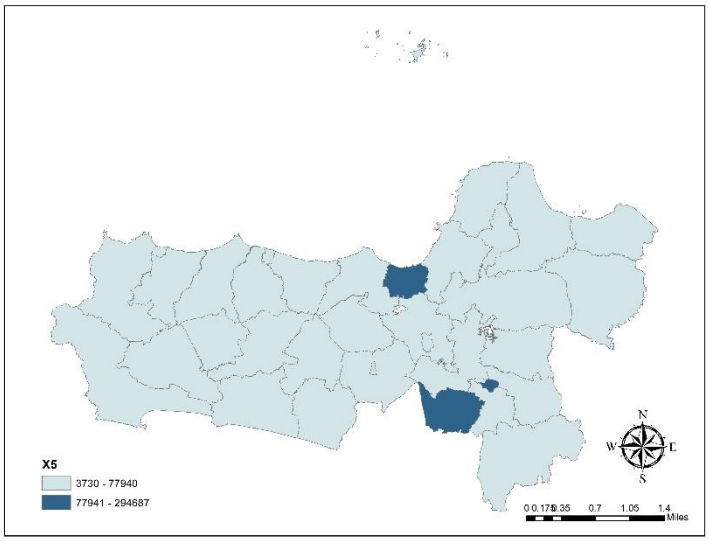

Figure 6. Spatial distribution of non-Muslim population in Central Java province

The distribution of the number of mosques in Central Java Province is shown in Figure 7. The figure shows that the darker the colour of the location, the more the number of mosques in

the region. It can be seen that the region with the highest number of mosques ranges from 231 to 3,357, while the region with the lowest number of mosques ranges from 3,358 to 7,931. Banyumas, Grobogan, Cilacap, Brebes, Kebumen, Banjarnegara, Jepara, Klaten, Blora, Demak, Boyolali, Semarang, Kendal, Batang, Magelang, Pemalang, Pati, Temanggung, and Wonogiri are the regions of the second cluster that have a large number of mosques.

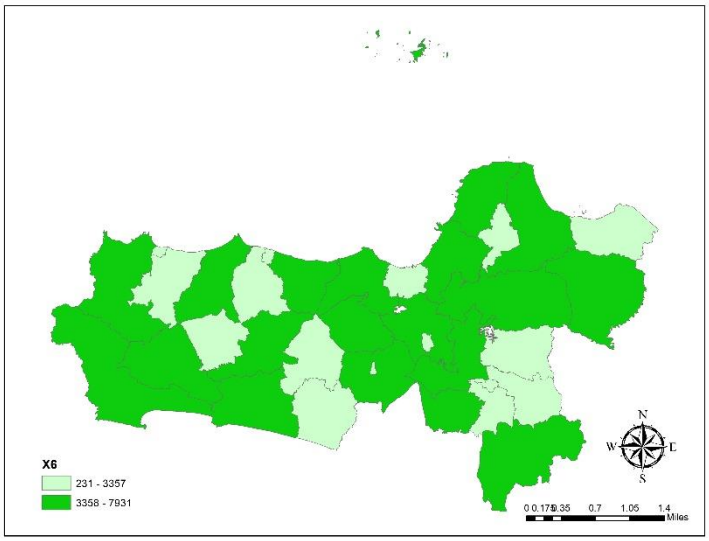

Figure 7. Spatial distribution of the number of mosques in Central Java province

The distribution of population density in Central Java Province is shown in Figure 8. In the figure it appears that the darker the colour of the location, the more population density in the region. It can be seen that the regions with the most population density range from 479 to 3,384, while the regions with the least population density range from 3,385 to 11,293. Surakarta City, Magelang City, Pekalongan City, Tegal City, and Semarang City are the second cluster regions that have the highest population density.

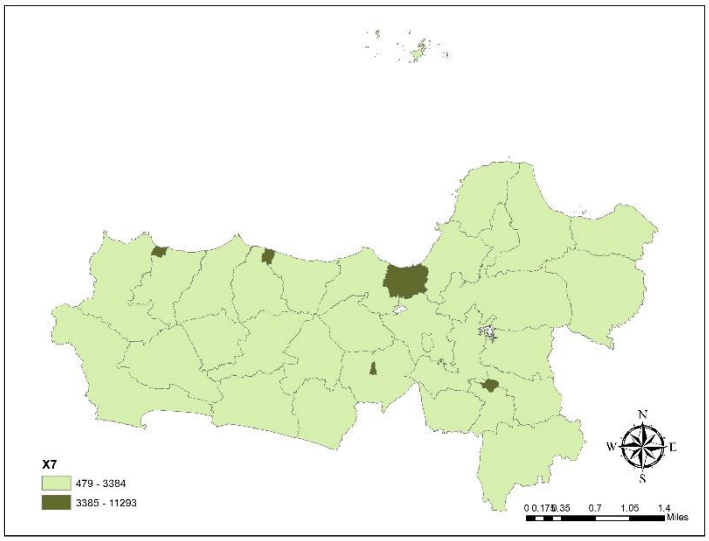

Figure 8. Spatial distribution of population density in Central Java province

2. Discussion

The teachings of Islam which are *rahmatan lil alamin* are flexible and universal (Hauser, 2012; Shehu, 2017). This makes the teachings of Islam applicable in all times and spaces. A well-known term to describe this is al-Islam shalih likulli zaman wa makan. Because of this characteristic, Islam cannot be identified with arabisation, but on the other hand it can be collaborated with any other culture where it is anchored. Islamic Da'wah is in contact with various regions of society (Suriati et al., 2020). One region with another has its own characteristics and characteristics. This can be seen from differences in mindset, culture and traditions expressed, life orientation, livelihoods, and also the natural conditions in which they live. This diversity affects people's acceptance of a religion and the spread of a religion in their lives.

The geographical-sociological mapping analysis as described above is an important consideration in the formulation of a da'wah approach strategy. In relation to the three main variables of da'wah mapping (subject, object, and environment), Islamic da'wah cannot be carried out with a uniform approach in all regions. Regional differences result in differences in da'wah approach strategies as well. There are differences in strategy between areas that are densely populated with Muslims and densely populated with non-Muslims; between areas that have many pesantren and few pesantren; between areas that are densely populated with *santri* and few *santri*; and between areas that have many houses of worship (mosques-mushalla) and few houses of worship.

The formulation of a targeted da'wah strategy must refer to the conditions of the local community based on the mapping above. Mapping does not only aim to see what and where are the potential da'wah areas, but more important than that is to explore the right da'wah strategy for these areas. Of course, the main keyword of da'wah for areas with diverse geographical-sociological backgrounds is 'inclusive da'wah'. Inclusive da'wah can simply be defined as da'wah that is open to dialogue with various other cultures (Ismail & Uyuni, 2020; Karim & Riyadi, 2024). Therefore, the strategic model of da'wah approach built in the context of differences in the potential of da'wah areas must stand on the principles of openness, justice-egalitarianism, welfare development, and peace. Areas that belong to the first cluster with lower da'wah potential than the second cluster can produce a new formulation or model in the da'wah approach strategy. The following will present a da'wah model that can be applied in the context of the da'wah potential above.

a. Da’wah between regions in the first and second clusters must be carried out comprehensively and collaboratively. This approach emphasizes the importance of cooperation between regions with higher da’wah potential in the second cluster and regions in the first cluster with lower da’wah potential. In this case, the regions in the second cluster, which show higher da’wah potential, can become a model or basis for developing da’wah programs for the regions in the first cluster. This collaboration will strengthen the da’wah network and enable the transfer of knowledge and experience from more developed regions to regions in need. Identifying each region's strengths and weaknesses in these two clusters is important. Areas with higher da’wah potential in the second cluster often have the more mature social and cultural infrastructure to support da’wah activities. In contrast, areas in the first cluster may face limited access to

religious education, low religious awareness, or even social disparities that exacerbate the da'wah process. Therefore, a collaborative approach that prioritizes synergy between these regions is essential to maximize the da'wah potential in each area.

b. Dawah subjects, such as *Kiyai* and *Santri*, who are in the second cluster, have great potential to collaborate with dawah subjects in the first cluster in carrying out dawah activities. This collaboration can form a broader and more effective dawah network, where the involvement of both parties reinforces and complements each other. In this context, the role of da'wah organizations with a strong institutional base, such as Nahdlatul Ulama (NU) and Muhammadiyah, can be optimized to support the spread of a more inclusive and well-organized da'wah. With their extensive networks and resources, these two organizations can play a major role in formulating a more holistic and comprehensive da'wah strategy, both locally and nationally. Cooperation between *Kiyai*, *Santri*, and these da'wah organizations can create stronger synergies in introducing da'wah with an approach that is more contextual and relevant to the needs of society. For example, da'wah organizations such as NU and Muhammadiyah, which have experience managing religious social activities, can provide logistical support, human resources, and even funds to expand the scope of da'wah. On the other hand, *Kiyai* and *Santri*, who have a deep understanding of Islamic teachings, can provide more in-depth da'wah content in accordance with the spiritual needs of the local community.
c. Based on the mapping of da'wah in this study, Surakarta is categorized as an area with a large non-Muslim population. This presents a challenge for the development of da'wah in the area, where tensions between Muslims and non-Muslims often arise. On the one hand, the existing diversity should be an opportunity to strengthen tolerance and cooperation between religious communities. However, on the other hand, the existence of groups that exploit religious issues for political gain can trigger sharper polarisation, even making matters worse by reinforcing radical views. One factor that exacerbates this situation is the political control that non-Muslim groups have in the public sphere, which sometimes creates dissatisfaction among some Muslims. In some cases, radical groups can take advantage of this situation to gain the sympathy of people who feel marginalized or neglected by the government or socio-political life. Thus, although regions such as Surakarta have great potential for peaceful and inclusive da'wah, they can be fertile ground for spreading extremist ideologies. On the other hand, a da'wah approach based on tolerance and mutual understanding between religious communities remains the long-term solution that needs to be prioritized. A more contextualized implementation of da'wah, tailored to local social and cultural conditions, will strengthen interfaith relations without damaging the harmony that has already been established. Therefore, it is important for preachers to not only focus on spreading religious teachings but also on raising social awareness about the importance of living peacefully side by side in a pluralistic society.

D. CONCLUSION AND SUGGESTIONS

This study contributes to Islamic studies, especially da'wah in Indonesia. The study was conducted using a spatial clustering algorithm approach. The spatial clustering algorithm used in this study is fuzzy geographically weighted clustering (FGWC) to optimise the clustering quality. The da'wah potential of each district/city in Central Java province varies, with each having a specific pattern of cluster formation. However, the distribution of the clustering results shows that each cluster has geographically close members. The FGWC analysis results indicate that each cluster's members tend to group together. For example, cluster one tends to group in districts/cities in the central part of Central Java province. In contrast, the second cluster tends to group together in districts/cities in the western and eastern parts of Central Java province. Furthermore, on average, in cluster one, there is one variable with a high value, while in the second cluster, there are six variables with high values.

Therefore, the areas included in the second cluster have high da'wah potential. In other words, the areas in the second cluster have the potential for developing inclusive da'wah that promotes moderate Islamic values (*rahmatan lil alamin*), so this potential must be continuously maintained and developed. Meanwhile, in the first cluster, there is diversity, so there is a mixture of religious orientation and material orientation (abangan, nationalists, fundamentalists) so this cluster requires special attention to carrying out inclusive da'wah development programmes. In addition, the differences in the potential for da'wah between regions in the cluster require a comprehensive and collaborative da'wah approach strategy so that regions with potential for da'wah can become a basis for the development of other regions where the potential for da'wah is still low. These results can be used as a strategy for mapping priority da'wah areas, allocating effective resources, and developing a more contextualised da'wah approach according to the characteristics of each cluster.

REFERENCES

Abdul Salam Noh Se Ik, Syaikhoni Jazuli, Rohmah, S., & Nur Chanifah. (2024). Principles of Islam and Social Integration. *Peradaban Journal of Religion and Society*, *3*(1), 18–32. https://doi.org/10.59001/pjrs.v3i1.146

Amin, J. J. A. (2012). Cultural landscapes of Java. In *Managing Cultural Landscapes 1st Edition*. Routledge. https://www.taylorfrancis.com/chapters/edit/10.4324/9780203128190-6/cultural-landscapes-java-jusna-amin

asmar, afidatul, & Perdana, D. A. (2024). Dakwah Dan Radikalisme (Pendekatan Pemahaman Mitra Dakwah). *Journal of Islamic Management*, *4*(1), 25–37. https://doi.org/10.15642/JIM.V4I1.1571

Astuti, C. C., & Untari, R. S. (2017). Applied Hierarchical Cluster Analysis with Average Linkage Algoritm. *CAUCHY: Jurnal Matematika Murni Dan Aplikasi*, *5*(1), 1–7. https://doi.org/10.18860/ca.v5i1.3862

Bharill, N., & Tiwari, A. (2014). Enhanced cluster validity index for the evaluation of optimal number of clusters for Fuzzy C-Means algorithm. *2014 IEEE International Conference on Fuzzy Systems (FUZZ-IEEE), Beijing, China, 2014, pp. 1526-1533*. doi: 10.1109/FUZZ-IEEE.2014.6891591

Carbone, A., & Ponta, L. (2022). Relative cluster entropy for power-law correlated sequences. *SciPost Physics*, *13*(3), 1–11. https://doi.org/10.21468/SciPostPhys.13.3.076

Dahiya, S., Gosain, A., & Mann, S. (2021). Experimental analysis of fuzzy clustering algorithms. In: Satapathy, S., Zhang, YD., Bhateja, V., Majhi, R. (eds) Intelligent Data Engineering and Analytics. Advances in Intelligent Systems and Computing, vol 1177. Springer, Singapore. https://doi.org/10.1007/978-981-15-5679-1_29

Doan, H., & Nguyen, D. (2018). A method for finding the appropriate number of clusters. *International Arab Journal of Information Technology*, *15*(4), 675–682. https://www.iajit.org/PDF/July 2018, No. 4/9993.pdf

Doya, H. (2020). Nilai-Nilai Humanisme dalam Novel 99 Cahaya di Langit Eropa. *Journal of Islamic Theology and Philosophy*, *2*(2), 111-120. https://doi.org/10.24042/ijitp.v2i2.6507

Eustáquio, F., & Nogueira, T. (2020). Evaluating the numerical instability in fuzzy clustering validation of high-dimensional data. *Theoretical Computer Science*, *805*, 19–36. https://doi.org/10.1016/j.tcs.2019.10.039

Ferraro, M. B. (2024). Fuzzy k-Means: history and applications. *Econometrics and Statistics*, *30*, 110–123. https://doi.org/10.1016/j.ecosta.2021.11.008

Gowda, S., Nandan, C. S., Jayaram, M. A., Gupta, A., & Jaya, R. S. (2024). Unsupervised Clustering of Asphalt Pavement Conditions Using Fuzzy C-Means Algorithm with Principal Component Analysis Aided Dimensionality Reduction. In: Verma, O.P., Wang, L., Kumar, R., Yadav, A. (eds) Machine Intelligence for Research and Innovations. MAiTRI 2023. Lecture Notes in Networks and Systems, vol 831. Springer, Singapore. https://doi.org/10.1007/978-981-99-8135-9_4

Grekousis, G. (2021a). Local fuzzy geographically weighted clustering: a new method for geodemographic segmentation. *International Journal of Geographical Information Science*, *35*(1), 152–174. https://doi.org/10.1080/13658816.2020.1808221

Grekousis, G. (2021b). Local fuzzy geographically weighted clustering: a new method for geodemographic segmentation. *International Journal of Geographical Information Science*, *35*(1), 152–174. https://doi.org/10.1080/13658816.2020.1808221

Guo, L., Chen, L., Lu, X., & Chen, C. L. P. (2020). Membership affinity lasso for fuzzy clustering. *IEEE Transactions on Fuzzy Systems*, *28*(2), 294–307. https://doi.org/10.1109/TFUZZ.2019.2905114

Hadi, B. S. (2017). *Pendekatan Modified Particle Swarm Optimization dan Artificial Bee Colony Pada Fuzzy Geographically Weighted Clustering*. Institut Teknologi Sepuluh Nopember. https://repository.its.ac.id/2721/

Hasan, I. K., Nurwan, Nur Falaq, & Muhammad Rezky Friesta Payu. (2023). Optimization Fuzzy Geographically Weighted Clustering with Gravitational Search Algorithm for Factors Analysis Associated with Stunting. *Jurnal RESTI (Rekayasa Sistem Dan Teknologi Informasi)*, *7*(1), 120–128. https://doi.org/10.29207/resti.v7i1.4508

Hauser, A. (2012). Da'wah: Islamic Mission and Its Current Implications. *International Bulletin of Missionary Research*, *36*(4), 189–194. https://doi.org/10.1177/239693931203600405

Hibrizi, A. N. (2024). Unsur-Unsur Komunikasi dalam Dakwah Rasulullah SAW dan Implementasi Strategi Dakwah Rasulullah di Era Digital. *Meyarsa: Jurnal Ilmu Komunikasi Dan Dakwah*, *5*(2), 116–126. https://doi.org/10.19105/MEYARSA.V5I2.15260

Ismail, A. I., & Uyuni, B. (2020). The New Perspective of Interfaith Dialogue as Da'wah Approach in Global Era. *Journal of Xidian University*, *14*(3), 1540–1552. https://repository.uinjkt.ac.id/dspace/handle/123456789/50860

Japar, M., Sahid, K., & Fadhillah, D. N. (2019). Social tolerance in multi-religious states: A case study in cigugur society, Indonesia. *International Journal of Innovation, Creativity and Change*, *7*(7), 371-392. https://www.ijicc.net/images/vol7iss7/7718_Japar_2019_E_R.pdf

Kadri. (2022). Religion and Tourism: Promoting Inclusive Islam in Lombok Island, Indonesia. *Studia Islamika*, *29*(2), 333–357. https://doi.org/10.36712/SDI.V29I2.14471

Kanzawa, Y. (2020). Generalization property of fuzzy classification function for tsallis entropy-regularization of bezdek-type fuzzy c-means clustering. In *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics): Vol. 12256 LNAI*. https://doi.org/10.1007/978-3-030-57524-3_10

Karim, A., Adeni, A., Fitri, F., Fitri, A. N., Hilmi, M., Fabriar, S. R., & Rachmawati, F. (2021). Pemetaan untuk Strategi Dakwah di Kota Semarang Menggunakan Pendekatan Data Mining (Mapping for Da'wah Strategy in Semarang City Using Data Mining Approach). *Jurnal Dakwah Risalah*, *32*(1), 40-55. https://doi.org/10.24014/jdr.v32i1.12549

Karim, A., & Riyadi, A. (2024). Analyzing big data of da'wah manuscripts based on Dimensions: Mapping research on da'wah on social media. *Jurnal Ilmu Dakwah*, *44*(1), 1–14. https://doi.org/10.21580/JID.V44.1.22073

Khasanah, S. U. (2022). Nahdlatul Ulama Da'wah Dynamics: Socio-Cultural Change and Disruption. *KOMUNIKA: Jurnal Dakwah Dan Komunikasi*, *16*(2), 183–199. https://doi.org/10.24090/komunika.v16i2.6810

Koltcov, S., Ignatenko, V., & Pashakhin, S. (2020). How Many Clusters? An Entropic Approach to Hierarchical Cluster Analysis. In: Arai, K., Kapoor, S., Bhatia, R. (eds) Intelligent Computing. SAI 2020. Advances in Intelligent Systems and Computing, vol 1230. Springer, Cham. https://doi.org/10.1007/978-3-030-52243-8_40

Kurniawan, R., & Haqiqi, B. N. (2015). Pengelompokan Menggunakan Metode Substractive Fuzzy C-Means (SFCM), Studi Kasus Demam Berdarah di Jawa Timur. *Jurnal Statistika*, *3*(2), 22-30. https://doi.org/10.26714/jsunimus.3.2.2015.%25p

Liao, Z. X., & Peng, W. C. (2012). Clustering spatial data with a geographic constraint: Exploring local search. *Knowledge and Information Systems*, *31*(1), pages 153–170. https://doi.org/10.1007/s10115-011-0402-8

Mahamadou, A. J. D., Antoine, V., Nguifo, E. M., & Moreno, S. (2020). Categorical fuzzy entropy c-means. *IEEE International Conference on Fuzzy Systems*, *2020-July*. https://doi.org/10.1109/FUZZ48607.2020.9177666

Mahmuddin, Hj.Ab Rahman, A., Haris, A., Citra Haris, A. T., & Hadriaty. (2018). Da'wah strategy in strengthening the community's economy in Bira village Bulukumba regency, Indonesia. *International Journal of Civil Engineering and Technology*, *9*(116–122), 116–122. https://iaeme.com/Home/article_id/IJCIET_09_12_015

Marfu'ah, U. (2018). Strategi Komunikasi Dakwah Berbasis Multikultural. *Islamic Communication Journal*, *2*(2), 147–161. https://doi.org/10.21580/icj.2017.2.2.2166

Muh Aditya Ibrahim, Eri R Hidayat, Halomoan FS Alexandra, Pujo Widodo, & Herlina JR Saragih. (2023). Horizontal Conflict Resolution Related to Belief in Religious Tolerance in Multi-Cultural Society in Indonesia. *International Journal Of Humanities Education and Social Sciences (IJHESS)*, *2*(6), 1925–1929. https://doi.org/10.55227/ijhess.v2i6.525

Muranishi, M., Honda, K., & Notsu, A. (2014). Xie-beni-type fuzzy cluster validation in fuzzy co-clustering of documents and keywords. In: Cho, Y., Matson, E. (eds) Soft Computing in Artificial Intelligence. Advances in Intelligent Systems and Computing, vol 270, 29-38. Springer, Cham. https://doi.org/10.1007/978-3-319-05515-2_4

Nasution, B. I., & Siregar, S. I. (2022). Regional Economy Condition in Indonesia during COVID-19 Pandemic: An Analysis using Teaching Learning-Based Fuzzy Geodemographic Clustering. *2022 1st International Conference on Information System and Information Technology, ICISIT 2022*, 37–42. https://doi.org/10.1109/ICISIT54091.2022.9873033

Nurjanah. (2024). SERVING AS A ROLE MODEL Historical Perspectives on Muhammadiyah's Multicultural Da'wa Towards Chinese Indonesians, 1960–1970. *Journal of Indonesian Islam*, *18*(2), 558–578. https://doi.org/10.15642/JIIS.2024.18.2.558-578

Popkov, Y. S., Dubnov, Y. A., & Popkov, A. Y. (2022). Entropy-Randomized Clustering. *Mathematics*, *10*(19), 1–15. https://doi.org/10.3390/math10193710

Riyadi, A., & Karim, A. (2023). Da'wah bil-hikmah: Tracing Sunan Kalijaga's footsteps in the transformation of Islamic society. *Jurnal Ilmu Dakwah*, *43*(2), 281–296. https://doi.org/10.21580/JID.V43.2.18468

Riyadi, A., Sulistio, S., & Karim, A. (2024). Social Harmony through Local Wisdom: Da'wah in the Kalang Obong Tradition. *Jurnal Dakwah Risalah*, *35*(1), 68–86. https://doi.org/10.24014/JDR.V35I1.29909

Rosmalina, A., & Khaerunnisa, T. (2021). Media Sosial Sebagai Alat Komunikasi Dakwah Pada Masa Pandemi. *ORASI: Jurnal Dakwah Dan Komunikasi*, *12*(1), 147-160. https://doi.org/10.24235/orasi.v12i1.8205

Setyoningrum, D. U., Warella, Y., & Yuningsih, T. (2021). Analysis of risks and challenges to demographic bonuses in sustainable development programs through population policy transformation (case study in Central Java Province). *IOP Conference Series: Earth and Environmental Science*, *623*(1), 012088. https://doi.org/10.1088/1755-1315/623/1/012088

Shehu, F. (2017). Methodology of Prophetic Da'wah and Its Relevance to Contemporary Global Society. *Journal of Education and Social Sciences*, *6*, 9–16. https://jesoc.com/wp-content/uploads/2017/03/JESOC-30.pdf

Singh, M., Bhattacharjee, R., Sharma, N., & Verma, A. (2017). An improved xie-beni index for cluster validity measure. *2017 4th International Conference on Image Information Processing, ICIIP 2017*, *2018-January*, 95–99. https://doi.org/10.1109/ICIIP.2017.8313691

Suherman, Y. N., & Rustandi, H. (2023). Dakwah Inklusif Kontemporer Nurcholis Madjid. *Journal of Islamic Social Science and Communication*, *2*(1), 33-42. https://doi.org/10.54801/jisscdiksi.v2i01.179

Sumargo, B., Kurniawan, R., Nasution, B. I., Firmansyah, A., Laksono, B. C., Gio, P. U., Isnaeni, M. A., Yusuf, M., & Tarigan, V. C. E. (2024). Green Infrastructure Vulnerability and Regional Poverty Reduction: New Sustainable Development Recommendations Based on a Spatial Clustering Approach. *Journal of Poverty*. July 2024, 1-24. https://doi.org/10.1080/10875549.2024.2379769

Suriati, Burhanuddin, & Nur, M. J. (2020). *Da'wah in Form of Ukhuwah Islamiyah*. Proceedings of the 1st Borobudur International Symposium on Humanities, Economics and Social Sciences (BIS-HESS 2019). 941–946. https://doi.org/10.2991/assehr.k.200529.198

Suzuki, Y., & Kanzawa, Y. (2025). Tsallis Entropy-Regularized Fuzzy Classification Maximum Likelihood Clustering with a t-Distribution. *Journal of Advanced Computational Intelligence and Intelligent Informatics*, *29*(2), 365–378. https://doi.org/10.20965/jaciii.2025.p0365

Tavakkol, B., Choi, J., Jeong, M. K., & Albin, S. L. (2022). Object-based cluster validation with densities. *Pattern Recognition*, *Vol.121*, 1-14. https://doi.org/10.1016/j.patcog.2021.108223

Tomašev, N., & Radovanović, M. (2016). Clustering evaluation in high-dimensional data. In: Celebi, M., Aydin, K. (eds) Unsupervised Learning Algorithms. Springer, Cham. pp 71–107. https://doi.org/10.1007/978-3-319-24211-8_4

Wawaysadhya, W., Oktafiani, T. U., Olivia, P. L. D., & Baruzzaman, M. (2022). Moderasi Beragama di Media Sosial: Narasi Inklusivisme dalam Dakwah. *AL MUNIR : Jurnal Komunikasi Dan Penyiaran Islam*, *13*(02), 118–132. https://doi.org/10.15548/AMJ-KPI.V13I02.4601

Wijayanto, A. W., Purwarianti, A., & Son, L. H. (2016). Fuzzy geographically weighted clustering using artificial bee colony: An efficient geo-demographic analysis algorithm and applications to the analysis of crime behavior in population. *Applied Intelligence*, *44*(2), 377–398. https://doi.org/10.1007/s10489-015-0705-7

Zamakhsyari Baharuddin, A., & Tinggi Agama Islam Negeri Majene, S. (2020). Dakwah Inklusif dalam Kerangka Maqāṣid Al-Sharī'ah: Studi Kasus Pola Interaksi Lintas Agama pada Masyarakat Kalukku (Inclusive Dakwah in The Framework of Maqāṣid Al-Sharī'ah: A Case Study of Cross-Religious Interaction Patterns in Kalukku Community). *Jurnal Dakwah Risalah*, *31*(2), 199–219. https://doi.org/10.24014/JDR.V31I2.11114

Zeng, X., Wang, S., Li, Q., Ruan, S., Yang, Q., & Xu, H. (2025). Highly improve the accuracy of clustering algorithms based on shortest path distance. *Information Sciences*, *Vol 710*, 1-25. https://doi.org/10.1016/j.ins.2025.122087

Zuhdi, M. H., Saleh, M., Abdullah, M. N., Mujib, L. S. Bin, & ... (2017). *Peta Dakwah Majelis Ulama Indonesia Nusa Tenggara Barat*. Sanabil, Mataram. ISBN 978-602-6223-55-5