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# Investigating the spatial basis clustering of smart tourism potential using fuzzy c-means

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**A B S T R A C T**

The expansion of tourism locations that are both creative and of high quality is a significant contributor to the expansion of the economy. The stages of tourism development that are influenced by the progression of information technology are represented by the term "smart tourism" in the context of the ecosystem of smart villages. Integrating micro-enterprises with tourist practices is one of the ways that may be utilised to speed up the development of villages. By implementing the concept of smart tourism, tourism integrated with information and communication technology (ICT) can potentially improve both the economics and the services provided by the tourism industry. This research aims to analyse the clustering of smart tourism potential possibilities within the Kemang sub-district. These areas' clustering depends on some variables, including infrastructure (access for tourists), innovation, technology, local wisdom, distinctiveness, and economic conditions. The Fuzzy C-Means (FCM) clustering approach is utilised. A Geographic Information System (GIS) is utilised to facilitate the process of determining which villages are included in each cluster. This is done to describe potential areas better. The value of the cluster evaluation using the Davies Boulding Index (DBI) obtained is 0.3819, and the number of clusters with the best performance is 3. There is a very potential cluster in Cluster 3, comprising two villages (Kemang and Atangsanjaya). A potential cluster was also detected in Cluster 2, comprising three villages (Tegal, Pondokudik, and Parakanjaya). Furthermore, a fairly potential cluster was detected in Cluster 1, consisting of three villages (Jampang, Pabuaran, and Bojong). Specifically, in the Kemang sub-district, it is anticipated that the findings of this study will provide an overview of possible sites for implementing environmentally conscious tourism.



## 1. Introduction

One of the industries that is impacted by the COVID-19 outbreak is the tourism industry. Additionally, the tourism industry is beginning to exhibit signs of improvement, which coincides with the recovery of the national economy. The rise in the number of visits from the local community and other countries may witness this. During November 2023, the number of trips taken by domestic tourists reached 60,33 million, representing a 12.02% increase compared to the same month in 2022. Over the year from January to November 2023, the number of international tourists who visited the country reached 10.41 million, representing an 110.86% increase compared to the same period in 2022 (Badan Pusat Statistik, 2024). In addition, the Ministry of Tourism and Creative Industries surveyed to boost the expansion of the tourism industry. The results of the

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survey revealed that the creation of tourism destinations that are both innovative and of high quality plays a significant role in the expansion of the tourism industry in the future. In addition, there is a requirement for sustainable tourism, the development of infrastructure and supporting facilities, and the preservation and development of local culture (Kemenparekraf/Baparekraf RI, 2023). According to the Travel and Tourism Development Index (TTDI), one of the pillars of evaluation is the utilisation of technology and information. In the 2021 evaluation, Indonesia was ranked 32nd in the world, an increase of eight places from its previous position, which was ranked 40 (Kemenparekraf/Baparekraf RI, 2022).

Tourism is a necessity for a large number of people, and the growth of technology-based tourism is highly necessary since it has the potential to offer more sophisticated tourism alternatives, which can improve commerce in the area (Trinanda, 2020). According to Suleman (2020), Buhalis (2020), and Rahmat et al. (2021), information and communication technology (ICT) is an essential component that contributes to the improvement of the tourism industry. A significant element in forming a smart tourism system is information and communication technology (Gajdošík, 2018; Boes, Buhalis, and Inversini, 2015; Vasavada and Padhiyar, 2016). According to Gretzel et al. (2015) and Li et al. (2016), smart tourism is a tourism platform that integrates information, communication, and technology (ICT) to provide services and information that are both efficient and informative to tourists. According to Buhalis & Amaranggana (2015), smart tourism is a form of tourism that integrates innovations in information technology with the knowledge and culture of the local community to enhance marketing, management, and business coverage to better satisfy the tourists' requirements. The primary obstacle that must be overcome to realise sustainable tourism founded on smart tourism is the empowerment of the community in a way that is truly done by, from, and for the community participating (Helmita et al., 2021). According to Muchammad Satrio Wibowo et al. (2023), community participation can boost the economy and conserve what is currently there, intending to foster a sustainable tourism atmosphere. As a result, the current government encourages villages to be advanced and independent to develop their various potentials (Tosida, Ardiansyah, et al., 2023). One way this is accomplished is by developing local tourism with the concept of tourism villages, which aims to empower local communities, improve the economy, and preserve their culture (Prihasta & Suswanta, 2020). One of the nine villages comprising Bogor Regency is the Kemang Sub-district, which lies within the regency. Geographically located in the northwestern portion of Bogor Regency, to the East, it borders Tajur Halang Sub-district; to the North, it borders Parung Sub-district; to the South, it borders Dramaga Sub-district; and to the northwest, it borders Ciseeng Sub-district. According to the information that was gathered, the emerging business sector in this sub-district is dependent on the home industry of Micro, Small, and Medium Enterprises (MSMEs) based on local wisdom and gender insight, particularly Tegal, and even the village has been established Kampung Batik New Normal Bogor. Nevertheless, the village is in the developing stage according to the Village Development Index (IDM). One method that can be used to accelerate village development is the merging of tourism and micro-enterprises. According to Jayawinangun et al. (2024), the abundance of natural resources and active human resources (HR) (Zamroni et al., 2015; Setya Yunas, 2019; Tosida et al., 2022), particularly in their micro, little, and medium-sized enterprises (MSMEs), gives them the potential to be exploited as a tourist village. One of the solutions for developing a village is creating a tourist village based on the concept of smart tourism. This is because the Smart Tourism base brings together small and micro businesses, which in turn bridges the community of the tourist village to introduce their tourism to the global market (Helmita et al., 2021). In the long run, this will affect the improvement of the community's economy. To hasten the growth of villages, one of the supporting components is the implementation of smart tourism. The attainment of smart villages is intended to speed up the development of villages. Smart tourism is also an essential component of the smart economy, according to Watson et al. (2020) and Widodo and Dasiah (2021). As a result, a clustering analysis of the potential for smart tourism in the district was carried out as part of this research. This clustering depends on several elements, including the road infrastructure (access for tourists), technological conditions, and economic conditions.

The Fuzzy C-Means (FCM) clustering approach is utilised. According to Barkouk et al. (2021), the FCM algorithm is a clustering technique that aims to divide the same cluster. This approach is used when a single object might be a member of many clusters, and the boundaries between the clusters are unclear (Purba et al., 2023). In addition, FCM possesses a high level of accuracy and a rapid calculation time (Agustini, 2017). Furthermore, it is more versatile than other clustering algorithms in managing complicated data structures (Zhang & Shen, 2014).

In the future, the data will be transformed into a map using a Geographic Information System (GIS), which will facilitate identifying which settlements are included in each cluster. This will allow for the description of possible areas. Geographic information systems (GIS) have extensive capabilities in mapping and analysis, and they can integrate spatial and non-spatial information into a single system (Tosida, Ardiansyah et al., 2023). Spatial modelling was also used in the process of conducting spatial analysis. The goal is to understand the patterns, correlations, and trends present in spatial data and make judgements based on location that have the potential to be used for smart tourism.

## 2. Literature review

### *2.1. Smart Tourism*

According to Ktona et al. (2022), Smart Tourism is a platform founded on integrated information and communication technology. This platform has elevated tourism to a greater social and economic dimension. According to Gretzel et al. (2015), "Smart Tourism" is a concept that incorporates the role of information and communication technology in providing and managing information and services that are most effective for travellers. The realisation of smart tourism necessitates the presence of supporting components. To begin, creating a database associated with tourism resources should be accomplished by utilising cloud computing and Internet of Things technologies. Second, the tourism sector should continuously innovate to develop regional strategies for tourist destinations. Third, broadening the industry's scope through real-time information platforms and bringing together local communities and those who supply tourism services (Irsyad et al., 2018). Among the components that make up smart tourism are smart locations, smart enterprises, and smart experiences, as stated by Díaz-González et al. in 2022. The Internet of Things, Mobile Communication, Cloud Computing, and Artificial Intelligence are the primary components of Smart Tourism, as stated by Guo et al. (2014). However, according to Femenia-Serra et al. (2019), the characteristics that constitute smart tourism are Data centrality, Real-time development, Based on context-awareness, and Co-created, and Cross-cutting issues. According to Pai et al. (2020), the characteristics of smart tourist technology include the following: accessibility, interactivity, personalisation, interactiveness, and security. In order to facilitate the efficient allocation of resources, such as infrastructure, human resources, and financial resources, smart tourism is promoted. According to Shafiee et al. (2019), it is also necessary to incorporate smart tourism resources at the micro level. This includes incorporating these resources in local communities, tourism enterprises, and other entities. Facilities and tourist attractions are examples of facilities included in smart tourism variables. Specifically, attractions, interactions with tourists, and the economy are the three factors that impact the success of smart tourism (Santoso, 2019).

### *2.2. Kaiser Mayer Olkin (KMO)*

According to Nafisah and Chandra (2017), the principal objective of the Kaiser Mayer Olkin (KMO) test is to ascertain whether or not all of the data that has been collected is adequate for factorisation. The hypothesis of the KMO is as follows: H_0: The amount of data is sufficient for factor analysis, and H_1: The amount of data is not sufficient for factor analysis.

Test statistics:

$$\mathrm{KMO} = \frac{\sum_{i=1}^{p}\sum_{j=1}^{p} r_{ij}^{2}}{\sum_{i=1}^{p}\sum_{j=1}^{p} r_{ij}^{2} + \sum_{i=1}^{p}\sum_{j=1}^{p} r_{ij}^{2}} \tag{1}$$

With $i = 1,2,3, ..., p$ and $j = 1,2, ..., p$ and $i \neq j$, $r_{ij}$ is the correlation coefficient (relationship between 2 variables) between variables $i$ and $j$, $a_{ij}$ is partial correlation coefficient (relationship between 2 variables controlling for other variables) between variables $i$ and $j$.

### *2.3. Fuzzy C-Means*

In 1967, Lotfi Zadeh presented the fuzzy logic theory as the foundation for the Fuzzy C-Means (FCM) algorithm. One of the methods for clustering data is called FCM, which is a technique in which the existence of data points in a cluster is decided by the degree to which they belong to the cluster. In 1981, Jim Bezdek was the one who first presented this method to the public (Bezdek et al., 1984). The first stage in establishing the cluster centre, which will designate the average location for each cluster, is the fundamental notion of FCM. This step is necessary because the initial state of the cluster centre is not yet correct. When the cluster centre and membership value of each data are improved consistently, it is possible to observe that the cluster centre will migrate closer to the most appropriate site. The Fuzzy C Means technique does not produce a fuzzy inference system as its output; rather, it produces a row of cluster centres and the membership degree of each item in each cluster (Kusumadewi & Purnomo, H., 2010). According to Ahmadi & Hartati (2013), There are six steps involved in the FCM Clustering Algorithm

1. Data that is to be clustered $X$, in the form of a matrix with dimensions n x m (where n represents the number of samples data and m represents the qualities of each data). The $i^{th}$ sample data ($i$ = 1, 2, ..., $n$), and the $j^{th}$ attribute ($j$ = 1, 2,... , m) is denoted by Xij. In accordance with the number of clusters that have been specified, distribute the data.
2. Determine a few of the important inputs that are required for the Fuzzy C-Means calculation, specifically:
   a. Number of clusters = $c$;
   b. Rank of weights = $m$;
   c. Maximum iterations = *MaxIter*;
   d. Smallest expected error = $\xi$
   e. Initial objective function = $P_0 = 0$;
   f. Initial iteration = $t = 1$;
3. Generate random numbers $\mu_{ik}$, ($i$ = 1, 2, ..., $c$; $k$ = 1, 2, ..., $n$) as the elements of the initial partition matrix U. Calculate the sum of each column:

$$Q_j = \sum_{i=1}^{n} \mu_{ik} \tag{2}$$

Qi is the sum of each column of random values in a matrix, and the amount of Q is determined by the number of criteria that are used for evaluation.

4. Perform the calculation using the equation to determine each cluster's midpoint value ($V_{kj}$).

$$V_{kj} = \frac{\sum_{k=1}^{n}((\mu_{ik})^w \times X_{ij})}{\sum_{k=1}^{n}((\mu_{ik})^w} \tag{3}$$

$V_{kj}$ denotes the centre point of each cluster, the number of $V_{kj}$ is determined by the number of clusters that will be generated, and n determines the total amount of data.

5. Determine the objective function at the $t^{th}$ iteration, and then calculate $P_t$

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

where $t$ represents the iteration being calculated; if the iteration begins at 1, then the iteration will begin again at the beginning of the calculation, and it will continue following the provisions of the iteration that is running now.

6. In the partition matrix, compute the change that has occurred.

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

with $i$ =1, 2, ⋯, $c$ and $k$ = 1, 2, ⋯, $n$

Iterations will continue to repeat if certain values or conditions have not been reached, as for these conditions are if: (|Pt - Pt-1|< ξ) or ($t$ >*MaxIter*) then stop where Pt is the cluster center of the $t^{th}$ iteration less than the expected error value or if t (number of iterations) is greater than the maximum iteration. However, if the iteration is repeated with $t$ + 1 will repeat the 4th process or calculate the cluster center again (Kusumadewi & Purnomo, H., 2010).

*2.4. Davies Bouldin Index (DBI)*

Among the internal cluster evaluations, DBI is one of the evaluations that measure the average similarity between each cluster (Sinaga & Yang, 2020). This evaluation determines whether or not the outcomes of the cluster may be assessed from the perspective of cohesiveness and separation. The concept of cohesion refers to the distance between data points, a measurement that seeks to determine how closely data points are clustered together. On the other hand, the separation of distance values is used to measure the difference in data between the various populations. According to Tukiyat and Djohan (2022), the method of measurement that utilises DBI involves computing the average value of each point in the data set. The DBI value that is the smallest indicates the optimal number of clusters available. Listed below are the actions that must be taken to calculate the Davies-Bouldin Index:

1. Sum of Square Within-Cluster (SSW): SSW represents the sum of squares within the cluster. Calculating the value of the Sum of Square inside-Cluster (SSW) value is one method that may be utilised to establish the level of cohesiveness inside an i-th cluster. A cluster's cohesion can be defined as the total of proximity or similarity of the data to the cluster centre point of a cluster that is followed throughout the cluster. The equation that is used to determine the sum of squares within the cluster (SSW) value is the same as the SSW equation, which is as follows:

$$SSW_i = \frac{1}{m_i} d(x_{j,} c_i) \tag{6}$$

$m_i$ is a number of data in the $i^{th}$ cluster, ci is the centroid of the $i^{th}$ cluster, and $d(x_j, c_i)$ = the distance of each data to centroid i calculated using Euclidean distance.

2. Sum of Square Between-Cluster (SSB): The Sum of Square Between-Cluster (SSB) method is utilised to determine the distance or separation between clusters. To determine the Sum of Square Between-Cluster (SSB) value, consider the following equation:

$$SSB_{i,j} = d(xi, xj) \tag{7}$$

where, $d(xi , xj)$ is the distance between data i and data j in another cluster.

3. Ratio: A good cluster has the highest possible separation and the lowest possible cohesiveness value. This is the ratio that defines a good cluster. The purpose of calculating the ratio ($R_{i,j}$) is to ascertain the comparison value between the $i^{th}$ cluster and the $j^{th}$ cluster to compute the ratio value owned by each cluster. There are four indices, denoted with $i$, $j$, k, and l, respectively, if there are four clusters. Indices i and j are used to show the number of clusters. Utilising Equation ($R_{i,j}$) allows for determining the ratio. It is necessary to utilise the following equation to ascertain the ratio:

$$R_{i,j,\ldots n}=\frac{SSW_i+SSW_j+SSW_n}{SSB_{i,j}+\cdots+SSW_{ni,nj}}. \tag{8}$$

$SSWi$ is Sum of Square Within Cluster at centroid I, $SSBi, j$ is Sum of Square Between Cluster of $i^{th}$ data and $j^{th}$ data in different clusters In Eq. (7) $n$ will continue the number of clusters selected provided $n_i$ is not equal to $n_j$.

4. Davies Bouldin Index (DBI), to determine the DBI value, the ratio value that was acquired from Equation 8 is utilised in Eq. (9), which is as follows:

$$DBI = \frac{1}{k}\sum_{i}^{k} = max_{i\neq j}\,(R_{i,j,\ldots}k) \tag{9}$$

$R_{i,j}$ means the ratio of the values of SSW and SSB. According to Agbaje et al. (2019), the conclusions that may be drawn from the calculation of the Davies Bouldin Index (DBI) are as follows: the better the cluster, the smaller the value of the Davies Bouldin Index (DBI) that is achieved (non-negative > = 0).

## 3. Material and Methods

The techniques of planning, data analysis with fuzzy C-means, system development, and implementation are the primary components of the research methodology utilised in this study. The Thinking Framework is shown in Fig. 1.

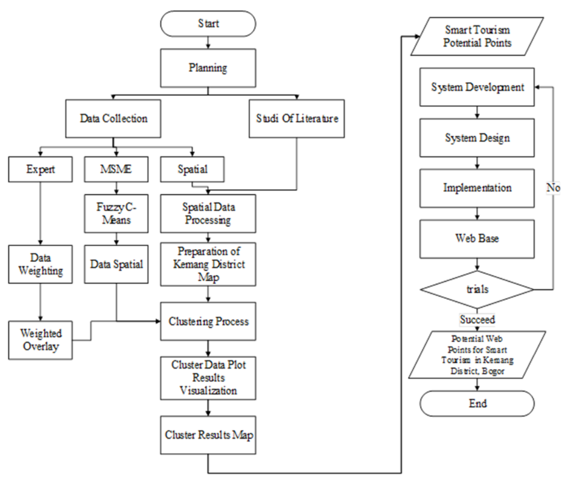



**Fig. 1.** Research flowchart using fuzzy C-Means algorithm for smart tourism potential clustering

### *3.1. Planning*

Following the completion of the planning stage, a literature review is carried out, in addition to collecting MSME data, shapefiles, and expert data. To determine the significance of smart tourism, MSME is administered to members of the community as well as professionals using a Google Form. The administrative maps of Kemang District are included in the data collection that is submitted as shapefiles.

### *3.2. Data Collection*

The data collection that will be utilised includes spatial data, data from MSMEs, and data from experts. According to Muchlis et al. (2019), the spatial data utilised in this investigation consisted of regional maps gathered from the Lapakgis website (https://www.lapakgis.com). Additionally, Indonesia-geospatial MSME data was utilised as one of the instruments in research, and data was collected by offering some questions or written statements. According to Tosida et al. (2022), the data on micro, small, and medium-sized enterprises (MSMEs) was gathered through a questionnaire containing eleven variables. These variables covered infrastructure conditions (tourist access), technological and economic conditions. These variables include the following:

$X_1$: Ability to access technology in the village

$X_2$: Ability to access the internet and other ICT in the village

$X_3$: Ability to access local, national and international markets

$X_4$: Ability to sustain local wisdom

$X_5$: Ability to interact with government, private sector, academics and media

$X_6$: Ability to access infrastructure (clean water, electricity and roads)

$X_7$: Variety of business opportunities in the village

$X_8$: Variety of ICT-based business opportunities (start-ups) in the village

$X_9$: Creativity and innovation ability

$X_{10}$: Non-ICT and ICT-based business capital capability

$X_{11}$: Ability to absorb labour.

Data gathered by experts Expert Data used in this study include the Head of Department in Kemang District, the Culture and Tourism Office (Disbudpar), and the Village Community Empowerment Office (DPMD). This research provides appropriate information for the completion of this research and provides support for research by providing adequate information. Expert opinion concerning the degree to which each community is prepared to embrace smart tourism (Santoso, 2019), with the following components that make up the variables:

$X_1$: Plans and strategies for sustainable tourism development programs (consists of 3 indicators)

$X_2$: Integrated tourism economy (consists of 4 indicators)

$X_3$: Access, attractions and tourist interaction (consists of 4 indicators)

$X_4$: Infrastructure and technology (consists of 5 indicators)

*3.3. Literature Study*

The term "literature study" refers to a procedure utilised in this research to acquire data or sources associated with the subject matter studied. Sources, including literature, journals, documentation books, the internet, and literature, can be utilised to acquire literary studies.

*3.3.1. System Development*

System development includes the stages that are involved in the construction of a geographical information system. This Geographic Information System aims to supply users with information using a map that can be accessed online. A map showing the results of data analysis with clustering, the use of fuzzy C-Means, and spatial modelling employing and their relevant regional information will be incorporated into the website. This map will be a representation of the map. The Fuzzy C-Means Clustering procedure is used to begin the analysis step. This process is performed with MSME data, which comprises infrastructure circumstances (tourist access), technology conditions, and economic variables analysed with the R Studio tool. After completing the clustering procedure and eliminating any moving points, the data will be transformed into a map. This will simplify identifying which villages are included in each cluster based on the information. The next step is to conduct a geographical analysis by employing spatial modelling with QGIS to identify possible places to develop smart tourism. The weighting process will be carried out by utilising the data provided by specialists and entering all required shapefiles. The administrative map of Kemang District and the expert questionnaire will be utilised as the data sources for the shapefile that will be utilised. In the future, this stage will look for an average, depending on the guidance of the expert. The information will be tested for validation with DBI, a method in which the information is known to be actual and is provided through direct observation and measurement. This will take place after the outcomes of potential points have been evaluated. If the validation test is unsuccessful, the Clustering procedure will be repeated; if it is successful, the data analysis process will be finished.

*3.3.2. Processing Fuzzy C-Means Clustering using MSME data with R*

Before beginning the clustering process, the MSME questionnaire feasibility test is first carried out. This test, also known as the sample assumption test representing the population, is designed to assess whether or not the MSME questionnaire is feasible. The Kaiser Meyer Olkin (KMO) testing apparatus was utilised for this examination. If the KMO value is greater than 0.5, the sample successfully reflects the population (Mahmudan, 2020). The results of the KMO Test using RStudio are shown in Fig. 2.

```
function(data){
x <- subset(data, complete.cases(data)) #menghilangkan data kososng (NA)
r <- cor(data)                          #membuat matrix kolerasi
r2 <- r^2                               #nilai koefisien untuk r squared
i <- solve(r)                           #inverse matrix dari matrix korelasi
d <- diag(i)                            #element diagonal dari inverse matrix
a2 <- (-i/sqrt(outer(d, d)))^2          #koefisien korelasi parsial kuadrat
diag(r2) <- diag(a2) <- 0               #menghapus element diagonal
KMO <- sum(r2)/(sum(r2)+sum(a2))
return(KMO=KMO)
}
> KMO(sd)
[1] 0.9086102
> |
```

**Fig. 2.** KMO Test

After going through the KMO Test procedure, the value produced was 0.9086102 for all lowered variables. As a result, the data can be representative of the population or to be representative of the population. Additionally, data standardisation is carried out to achieve parity between the various data units. As a result of the fact that the MSME data that is utilised is comprised of various units, it is necessary to standardise the data to make the units identical. The standardisation results are shown in Fig. 3.

| | No | X1 | X2 | X3 | X4 | X5 | X6 | X7 | X8 | X9 | X10 | X11 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | -1.4605935 | -1.128603113 | -1.17649738 | -0.9216000 | -1.32087051 | -1.34440381 | -1.20013717 | -1.19635103 | -0.9651385 | -0.89602545 | -0.3134956 | -0.9521144 |
| 2 | -1.0954451 | 0.006638842 | 0.27796367 | 0.3126857 | 0.52269742 | 0.53515103 | 0.39433078 | 0.33452469 | 0.4017328 | 0.36777164 | 0.3253256 | 0.3384021 |
| 3 | -0.7302967 | -0.172609888 | -0.07110698 | -0.1316571 | 0.07769827 | -0.28715421 | -0.06857927 | -0.27782559 | -0.3037492 | -0.05349406 | -0.2602605 | -0.3326665 |
| 4 | -0.3651484 | -1.068853536 | -0.94378361 | -1.1190857 | -1.13015658 | -0.93325119 | -1.09726827 | -1.04326345 | -1.1856016 | -0.59512138 | -0.6861413 | -1.1585971 |
| 5 | 0.0000000 | 1.500378256 | 1.49971095 | 1.3494857 | 1.15841050 | 1.23998410 | 1.32015088 | 1.04893336 | 1.1072148 | 1.57138792 | 1.6562032 | 1.3191947 |
| 6 | 0.3651484 | 0.962632067 | 0.91792653 | 1.2013715 | 1.03126788 | 1.12251192 | 0.96010973 | 0.94687498 | 1.1072148 | 1.39084548 | 1.5497330 | 1.2675741 |
| 7 | 0.7302967 | -1.009103960 | -1.00196205 | -1.3165715 | -1.06658528 | -1.16819554 | -1.30300607 | -1.14532183 | -1.2296943 | -1.13674871 | -0.8990817 | -1.0553558 |
| 8 | 1.0954451 | -0.232359464 | -0.59471296 | -0.2304000 | -0.30372958 | -0.05220986 | 0.08572408 | -0.07370883 | -0.1273787 | 0.30759083 | -0.2602605 | -0.3842872 |
| 9 | 1.4605935 | 1.141880797 | 1.09246185 | 0.8557715 | 1.03126788 | 0.88756756 | 0.90867528 | 1.40613770 | 1.1954000 | -0.95620627 | -1.1120222 | 0.9578501 |

**Fig. 3**. Data Standardisation

Following the data standardisation process, the subsequent step is to import MSME data files to edit them within the RStudio application. The results of the import file are displayed in Fig. 4, and the file type.csv is the one that is utilised for the import process.

| | X1 | X2 | X3 | X4 | X5 | X6 | X7 | X8 | X9 | X10 | X11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 3 | 4 | 3 | 4 | 4 | 4 | 3 | 3 | 3 | 3 | 3 |
| 2 | 3 | 3 | 3 | 3 | 3 | 3 | 2 | 2 | 1 | 1 | 1 |
| 3 | 2 | 2 | 1 | 2 | 1 | 1 | 2 | 2 | 1 | 1 | 3 |
| 4 | 2 | 2 | 1 | 2 | 2 | 1 | 2 | 2 | 1 | 2 | 2 |
| 5 | 2 | 2 | 2 | 3 | 2 | 1 | 2 | 1 | 1 | 1 | 2 |
| 6 | 2 | 2 | 1 | 2 | 1 | 1 | 2 | 1 | 1 | 1 | 2 |
| 7 | 2 | 2 | 1 | 2 | 2 | 1 | 2 | 1 | 2 | 1 | 2 |
| 8 | 1 | 2 | 1 | 1 | 2 | 1 | 2 | 1 | 1 | 1 | 1 |
| 9 | 2 | 1 | 2 | 3 | 1 | 3 | 2 | 3 | 1 | 1 | 2 |
| 10 | 2 | 1 | 1 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 |
| 11 | 2 | 1 | 2 | 2 | 1 | 2 | 2 | 1 | 2 | 3 | 2 |
| 12 | 3 | 2 | 3 | 3 | 3 | 2 | 2 | 3 | 2 | 3 | 3 |
| 13 | 1 | 1 | 1 | 2 | 2 | 1 | 2 | 1 | 1 | 1 | 2 |

**Fig. 4.** File Import Results

In the subsequent phase, it is necessary to do clustering using RStudio, employing the code fcm <- fanny (standard deviation, 3, metric = "euclidean", stand = FALSE). Fig. 5 illustrates the results that were obtained from this Clustering method.

```
  [1] 1 2 2 2 2 2 2 2 2 2 2 1 2 2 2 2 2 1 1 1 1 1 3 3 1 1 1 1 1 1 2 3 1 2 3 2 1 1 1 1 2 3 3 2
 [45] 2 1 3 1 1 1 3 3 2 1 3 3 3 3 3 3 3 1 2 1 1 3 3 1 1 1 3 2 1 2 2 2 2 3 2 1 2 2 1 1 1 1 1 1
 [89] 1 1 1 3 2 2 1 3 3 3 3 1 1 3 2 2 1 1 2 2 2 2 1 1 2 1 2 2 2 2 2 2 2 2 2 2 1 1 1 1 2 3 3 1
[133] 1 3 3 3 3 3 3 3 3 3 3 3 3 1 1 1 3 1 3 1 1 1 1 3 3 3 3 3 3 3 3 3 3 1 2 1 1 1 1 1 1 3 3 3
[177] 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 1 1 1 3 2 1 2 1 2 2 3 2 3 1 2 2 2 2 2 2 2 2 2 2 2 1
[221] 1 3 1 1 1 1 1 1 2 3 2 1 2 1 1 1 2 1 1 1 1 3 1 1 2 1 3 1 2 3 1 2 2 2 2 2 2 3 3 3 1 2 1 2
[265] 1 3 1 1 1 1 2 1 3 3 3 3 3 1 3 3 3 3 3 3 1 1 3 2 2 2 1 3 3 3 1 3 3 3 1 3
> |
```

**Fig. 5**. Clustering Results

This clustering aims to identify the potential village cluster for smart tourism in the Kemang District of Bogor. This clustering process has formed three clusters: potential, fairly potential, and extremely potential.

### *3.3.3. Weighting Data from Experts*

The value of a NAMOBJ field is referred to as the data weighting. This weighting of the data is performed on several different experts. This weighting aims to determine which village-level location is the most suitable for utilisation. This data weighting was carried out by 11 experts from several villages in Kemang sub-district, namely Expert 1 Secretary of Bojong Village, Expert 2 Head of Pondokudik Village Government Section and Expert 3 from the Head of Pabuaran Village Government Section, Expert 4, Secretary of West Semplak Village, Expert 5 from the Head of Atangsenjaya Village Government Section, Expert 6 Secretary of Kemang Village, Expert 7 head of Parakan Jaya Village Government Section, Expert 8 Head of Tegal Village Government Section Expert 9 Secretary of Jampang Village, Expert 10 Tourism & Creative Economy HR, and Expert 11 DPMD Office Staff. Figure 6 depicts the total weighting of the information provided by the experts.

| Desa | X1 | X2 | X3 | X4 | X5 | X6 | X7 | X8 | X9 | X10 | X11 | X12 | X13 | Cluster |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Kasi Pemerintahan Kel. Atangsenjaya | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 3 |
| Sekdes Desa Bojong | 5 | 3 | 4 | 4 | 4 | 4 | 5 | 5 | 5 | 4 | 4 | 5 | 5 | 1 |
| Sekdes Desa Jampang | 4 | 4 | 4 | 5 | 4 | 4 | 5 | 5 | 5 | 3 | 3 | 4 | 2 | 1 |
| Sekdes Desa Kemang | 5 | 5 | 5 | 5 | 5 | 5 | 3 | 5 | 3 | 4 | 3 | 3 | 4 | 3 |
| Kasi Pemerintahan Desa Pabuaran | 5 | 3 | 4 | 4 | 4 | 4 | 4 | 5 | 1 | 3 | 5 | 3 | 4 | 1 |
| kasi Pemerintahan Desa Parakanjaya | 5 | 2 | 4 | 4 | 4 | 4 | 3 | 3 | 4 | 3 | 3 | 3 | 3 | 2 |
| Kasi Pemerintahan Desa Pondokudik | 4 | 3 | 4 | 4 | 4 | 4 | 3 | 4 | 5 | 3 | 4 | 4 | 3 | 2 |
| Semplak Barat | 4 | 3 | 4 | 4 | 4 | 5 | 5 | 5 | 4 | 4 | 4 | 4 | 4 | 1 |
| Kasi Pemerintahan Desa Tegal | 5 | 1 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 3 | 3 | 4 | 3 | 2 |
| Kabid SDM Pariwisata dan Ekonomi Kreatif | 5 | 4 | 5 | 5 | 5 | 5 | 5 | 3 | 5 | 5 | 5 | 5 | 4 | |
| Staff DPMD | 2 | 4 | 5 | 5 | 5 | 5 | 5 | 3 | 5 | 4 | 4 | 4 | 4 | |

**Fig. 6**. Expert Weighting

The procedure for weighted overlay will be modified to incorporate the experts' weightings. A total of the weights will be tallied, and then the experts' average will be determined. In addition, the Weighted Overlay method involves classifying the criteria into raster-based data layers and then integrating them with Weighted Overlay by the weights that the specialists provide. The input for the Weighted Overlay shapefile is comprised of expert data in the Comma Separated Value (CSV) format. This data is turned into polygons and then converted back into a raster. Figure 7 illustrates the input that is used for the weighted overlay.

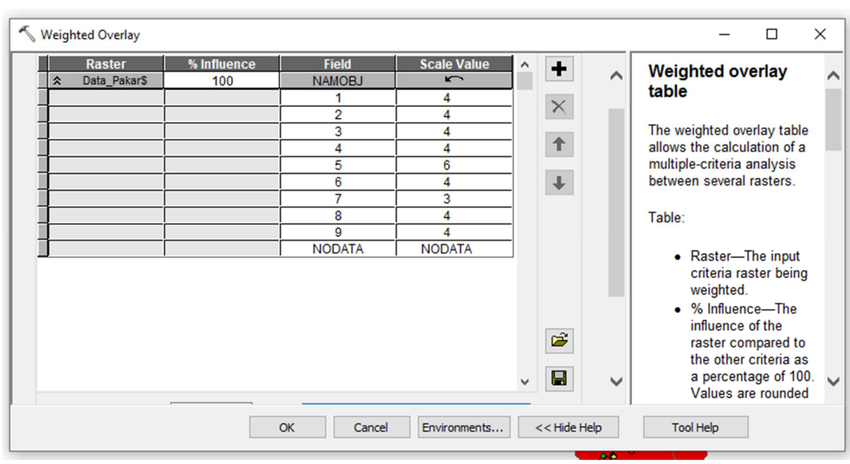



**Fig. 7.** Input weighting into Weighted Overlay

### *3.3.4. Spatial Data Processing*

At this point, the data from the shapefile, namely the Bogor Regency Boundary map, will be removed from the WADMKC attribute and taken based on the Kemang Subdistrict in the Village Boundary map table. This will result in the shapefile data becoming an administrative map of the Kemang Subdistrict, as depicted in Fig. 8.

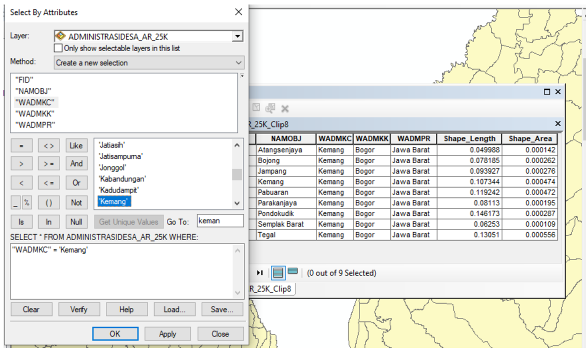



**Fig. 8**. Village Selection in Kemang Sub-district

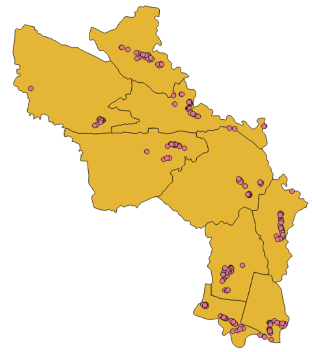


**Fig. 9.** Map of Kemang Subdistrict

Fig. 8 depicts the procedure for choosing which villages will be included in the Kemang Subdistrict. This method of selecting villages uses the Select by Attribute function available on the Bogor District Boundary map. This feature filters the results based on the attributes shown in the table. In addition, the village selection findings are included in a new map that is used to prepare a distinct map for the Kemang Subdistrict. The steps involved in completing the process include utilising the Select by Attribute function and then performing a Clip on the Bogor Regency Boundary map. A representation of the outcome of the Kemang Sub-district Map may be found in Fig. 9.

*3.3.5. Implementation*

The stage of the implementation process is the step in which a system designed in the past is constructed to transform it into an information system application that can be utilised. Two steps are involved in implementing Web GIS Potential Points for Smart Tourism in Kemang District. The first stage involves implementing the database using MySQL, and the second stage involves constructing the system using Visual Studio Code.

## 4. Result and Discussion

The data gathered is 300 respondents from villages, totalling 11 qualities or variables, and the data type has become a numeric number. This information was obtained based on the findings of interviews that were carried out in the Kemang District. A Fuzzy C-Means algorithm is then utilised to carry out the implementation.

*4.1. The result of Fuzzy C-Means Clustering using RStudio*

Cluster 1 members comprised 85 respondents, cluster 2 members comprised 109 respondents, and cluster 3 members comprised 105 respondents. These results were achieved by the utilisation of R Studio for the processing of fuzzy C-means clustering operations. Cluster 1 is a cluster for places with a moderate amount of potential, cluster 2 is a cluster for areas with potential, and cluster 3 is a cluster dedicated to areas with a great deal of potential. As can be seen in Figure 10, the plot data visualisation of the Clustering findings is presented.

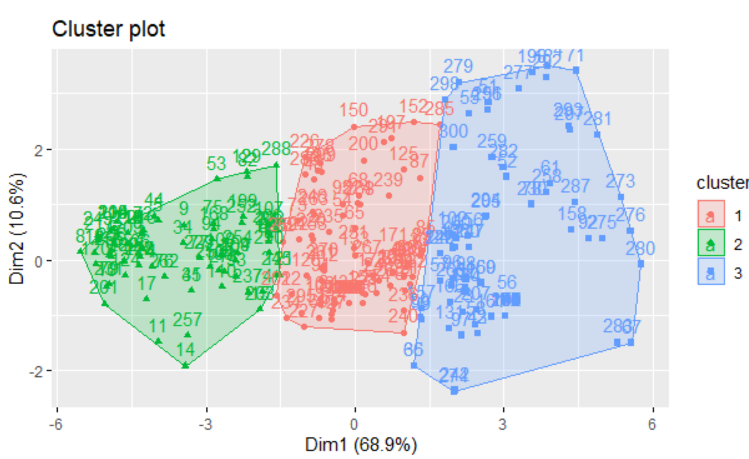



**Fig. 10**. Plot data visualisation of the Clustering results

Cluster 3 has the highest total attribute value, cluster 2 has a total attribute value lower than cluster 3, and cluster 1 has the lowest total attribute value. This information is based on Figure 10. In light of this, it is possible to conclude that Very Potential Villages are located in Cluster 3, Potential Villages are located in Cluster 2, and Fairly Potential Villages are located in Cluster 1. These are the data that are produced by this cluster: It is considered to be a fairly promising village since the micro, small and medium-sized enterprise (MSME) that is included in cluster 1 has a significant quantity of road infrastructure (X7) and transportation (X8), but it does not have sufficient economic or market facilities (X2). In addition, the number of roads and other transport infrastructure in the villages comprising Cluster 2 is fewer than that of Cluster 1. Still, some business and market facilities are sufficient. Because all of the characteristics have high values, it is possible that the villages included in cluster 3 satisfactorily fulfil all of the requirements. The two villages that are part of cluster 3 can be seen from the geography; these factors play a role in determining the placement of Smart Tourism in the Kemang District.

### 4.2. Spatial Modelling

The spatial modelling of data in QGIS is carried out at the stage of integrating geographic data and MSME data. At this stage, it is essential to ensure that the data type in MSMEs is correct to enable tables to be carried out. Selecting by attribute is the first step at this stage. The objective is to select vector data based on attributes, with attribute selection based on the village name. The second step is to add the cluster result data processed with RStudio and coordinate points. Finally, the data is joined, combining cluster result data and coordinate point data to achieve the desired result. The process results are displayed in Fig. 11 once carried out.

| NAMOBJ | WADMKC | X1 | X2 | X3 | X4 | X5 | X6 | X7 | X8 | X9 | X10 | X11 | Cluster | X | Y |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bojong | Kemang | 3 | 4 | 3 | 4 | 4 | 4 | 3 | 3 | 3 | 3 | 3 | 1 | 106.7502 | -6.53047 |
| Bojong | Kemang | 3 | 3 | 3 | 3 | 3 | 3 | 2 | 2 | 1 | 1 | 1 | 2 | 106.7502 | -6.53071 |
| Bojong | Kemang | 2 | 2 | 1 | 2 | 2 | 1 | 2 | 2 | 1 | 2 | 2 | 2 | 106.7486 | -6.53635 |
| Bojong | Kemang | 2 | 2 | 2 | 3 | 2 | 1 | 2 | 1 | 1 | 1 | 2 | 2 | 106.7492 | -6.53626 |
| Bojong | Kemang | 2 | 2 | 1 | 2 | 1 | 1 | 2 | 1 | 1 | 1 | 2 | 2 | 106.7491 | -6.53644 |
| Bojong | Kemang | 2 | 2 | 1 | 2 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 2 | 106.7495 | -6.53633 |
| Bojong | Kemang | 1 | 2 | 1 | 1 | 2 | 1 | 2 | 1 | 1 | 1 | 1 | 2 | 106.7502 | -6.53055 |
| Bojong | Kemang | 2 | 1 | 2 | 3 | 1 | 3 | 2 | 3 | 1 | 1 | 2 | 2 | 106.7503 | -6.53059 |
| Bojong | Kemang | 2 | 1 | 1 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 2 | 106.7502 | -6.53066 |
| Bojong | Kemang | 2 | 1 | 2 | 2 | 1 | 2 | 2 | 1 | 2 | 3 | 2 | 2 | 106.7503 | -6.53075 |
| Bojong | Kemang | 3 | 2 | 3 | 3 | 3 | 2 | 2 | 3 | 2 | 3 | 3 | 1 | 106.7503 | -6.53134 |
| Bojong | Kemang | 1 | 1 | 1 | 2 | 2 | 1 | 2 | 1 | 1 | 1 | 2 | 2 | 106.7501 | -6.53136 |
| Bojong | Kemang | 2 | 2 | 1 | 2 | 1 | 2 | 2 | 2 | 3 | 3 | 2 | 2 | 106.7503 | -6.53146 |
| Bojong | Kemang | 2 | 3 | 2 | 2 | 3 | 2 | 2 | 3 | 2 | 3 | 3 | 2 | 106.749 | -6.53204 |
| Bojong | Kemang | 2 | 2 | 1 | 1 | 1 | 1 | 2 | 2 | 1 | 1 | 2 | 2 | 106.7487 | -6.53203 |
| Bojong | Kemang | 2 | 2 | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 2 | 106.7486 | -6.53225 |
| Bojong | Kemang | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 1 | 106.7485 | -6.53332 |
| Bojong | Kemang | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 1 | 106.7486 | -6.53278 |
| Bojong | Kemang | 3 | 3 | 3 | 3 | 3 | 3 | 2 | 2 | 2 | 2 | 2 | 1 | 106.7491 | -6.53257 |
| Bojong | Kemang | 4 | 4 | 4 | 3 | 3 | 3 | 3 | 4 | 3 | 3 | 3 | 1 | 106.7497 | -6.53131 |
| Bojong | Kemang | 3 | 3 | 2 | 3 | 3 | 3 | 3 | 2 | 2 | 2 | 3 | 1 | 106.7496 | -6.53181 |
| Bojong | Kemang | 4 | 4 | 3 | 4 | 4 | 4 | 4 | 3 | 4 | 4 | 3 | 3 | 106.7486 | -6.53168 |

**Fig. 11.** Data Join Result

The following step, which comes after joining, is to cluster the data. The clustered data is then coloured using symbology, and the value of the cluster determines the colouration. Cluster 1, or Fairly Potential, is represented by the colour red. Cluster 2, or potential, is represented by yellow, and cluster 3, or Very Potential, is represented by green. The map of the findings of the cluster analysis may be shown in Figure 12.

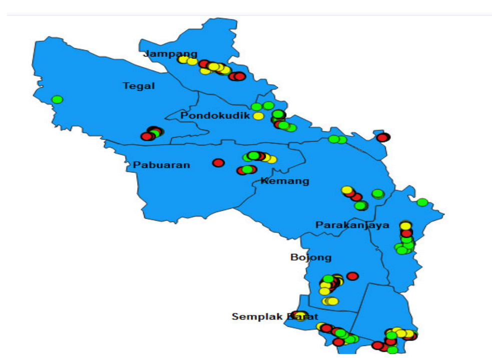



**Fig. 12**. Results of Cluster Data

Completing the Cluster Data using QGIS process, Fig. 13a reveals three clusters. Atang Senjaya Village includes 25 members, Bojong Village has three members, Jampang Village has nineteen members, Kemang Village has twenty-two members, Pabuaran Village has seven members, Pondokudik Village has fifteen members, West Semplak Village has three members, and Tegal Village has seven members collectively. This cluster has 105 members. The next step in creating the Clustering map of the cluster results using the Join Table function is carried out in QGIS. This step involves importing the data produced by the cluster into the map of the Kemang District. Symbology is used to colour the Kemang sub-district map with the cluster value. This is done in the process of mapping the cluster findings. Symbolism for Cluster 1 is represented by the colour red, followed by Cluster 2, which is represented by the colour yellow, and finally, cluster 3, which is represented by the colour green. Fig. 13a depicts the cluster result map, and Fig. 13b depicts the MSME Distribution Map. Both representations can be found in Fig. 13.

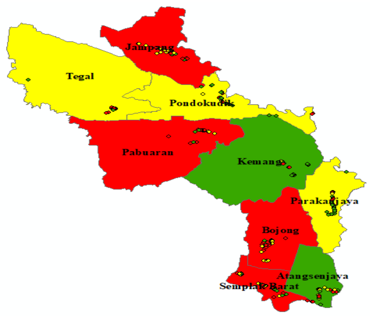



**Fig. 13a**. Clustering Map

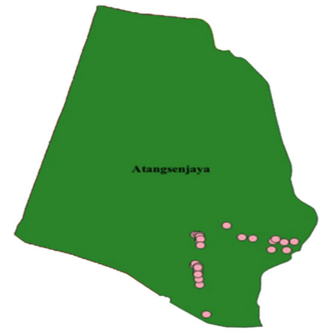


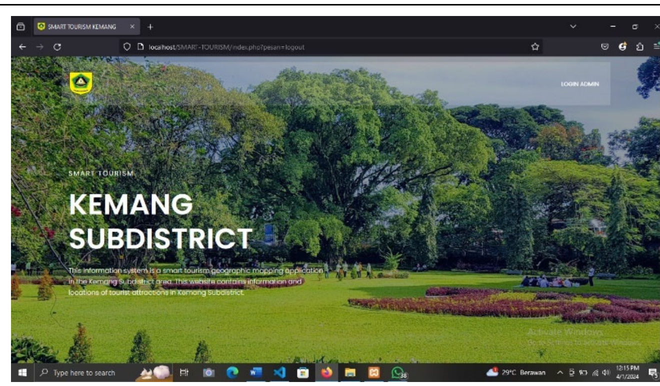
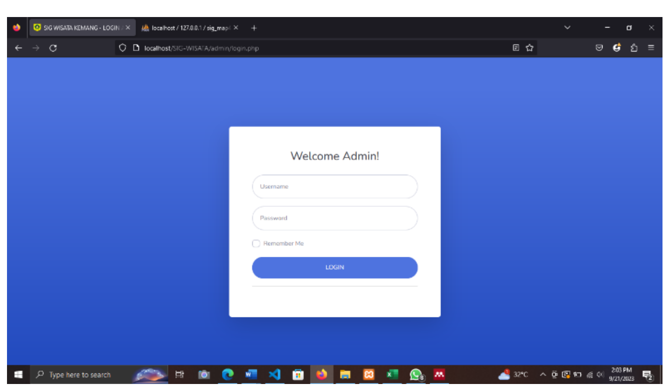

**Fig. 13b**. Distribution of MSMEs

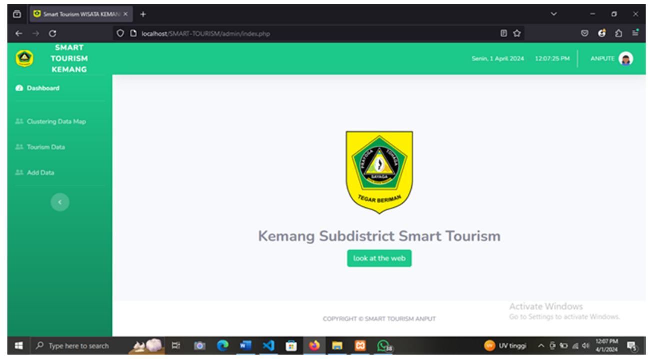
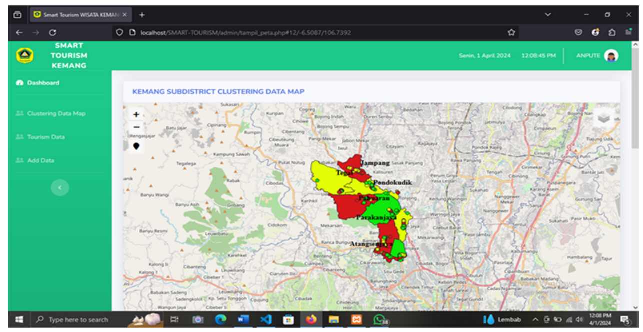
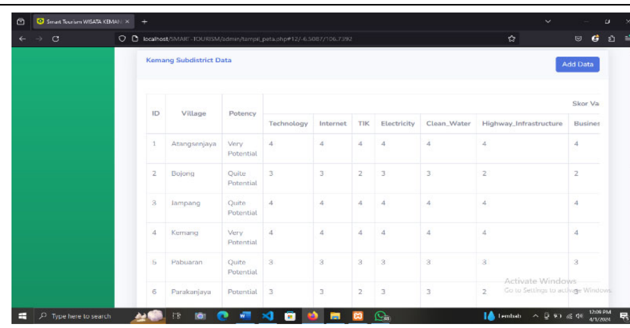
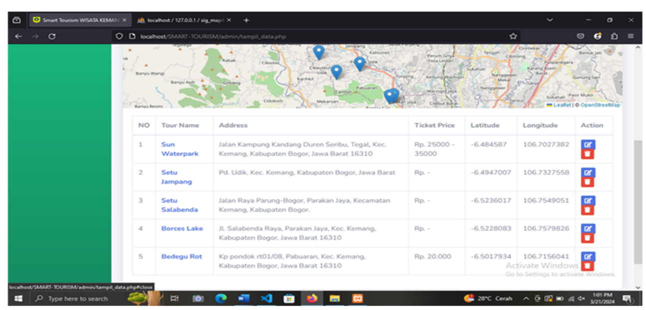
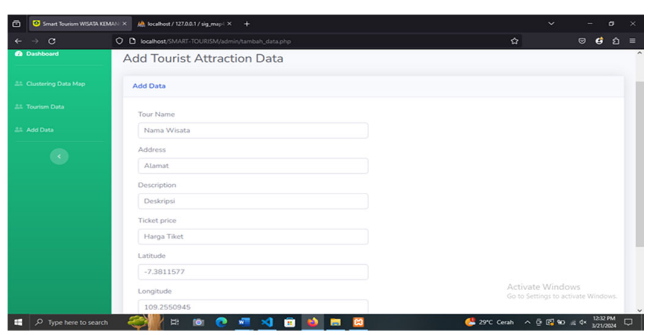
A cluster map is obtained based on the clustering data processing outcomes. This map is then divided into three clusters: cluster 1 has sufficient potential, which includes West Semplak Village, Bojong Village, Pabuaran Village, and Jampang Village; cluster 2 has potential, which includes Parakanjaya Village, Tegal Village, and Pondokudik Village; and cluster 3 has very potential, which includes Atangsenjaya Village and Kemang Village. According to the findings of the Clustering map that is included in cluster 3, Atangsenjaya Village is, in fact, well-known for its military area; however, there are UMKM, restaurants, and culinary delights that have the potential to serve as tourist destinations. Some examples of these include batik batik craft houses, pondok Bakso arema, Kapuk market, kripik Tempe, Chopper Café, and Bakmie Mba Git.

### *4.3. Website for Smart Tourism Potential Points*

The outcomes of the Smart Tourism potential spots website showcase the outcomes of spatial processing in QGIS and village cluster mapping from RStudio. The website brought about these outcomes. A single user level, the administrator, is included on the website associated with Smart Tourism potential points. Administrative personnel have the authority to add, modify (edit), and remove content. Investors or members of the general public can support the prospective points generated from the Clustering spatial processing because of this website. The website presentation can be found in Table 1.

**Table 1**
Website display for Smart Tourism Potential Points

| No | Description | Image |
|---|---|---|
| 1 | Default Menu In addition to the Admin Login feature, this page also has features for Tourism Data and Cluster Maps. Display includes these features. Through the use of the Tourism Data feature, it is possible to enter, modify, and remove data for each individual village. Regarding the Cluster Map page, it is equipped with a function that allows the user to select the map that will be displayed in the form of a possible image of a village map. |   |
| 2 | This page is the login form page, and only the administrator is permitted to log in. The administrator has the power to add, edit, and delete content. |   |

| No | Description | Image |
|---|---|---|
| 3 | Information on the Clustering Map, Tourism Data, and Add Data may be found on the Dashboard Page, which is a page that contains the features of the Smart Tourism website. The purpose of the clustering map feature is to display a map of cluster results with spatial points. The tourism data feature is designed to display a list of tourist data in the Kemang sub-district. The add data feature is designed to enter new tourist data. |   |
| 4 | On the Clustering Map Page, there is a function that allows you to set the map that will be displayed in the form of a cluster map image. This image will contain spatial points that have been converted into potential points during the process. The findings of the clustering process prompted the creation of this coloured map. |   |
| 5 | On the Kemang sub-district data page, you will find a list of villages that are located within the Kemang sub-district. These villages are categorised into three clusters: promising, rather promising, and highly promising. |   |
| 6 | The Tourist Data Page is a list of tourist data that is housed inside the Kemang sub-District. This page has capabilities that allow users to search for, modify, and delete tourist data for the district. |  |
| 7 | On the Add Data Page, there is a function that allows you to input tourist data such as the name, address, description (if you don't know, you can put a mark (-)), ticket price (if you don't know, you can put a mark (-)), latitude (horizontal line), and longitude (latitude). |   |

### *4.4. Cluster Validation Test*

It is possible to apply the DBI method to analyse the results of a cluster using a clustering approach. Coherence and separation are the basis for this systematic approach. It has been demonstrated by Shabrina et al. (2023) that the cluster produced by the Fuzzy C-Means algorithm will be of higher quality when the DBI value achieved is smaller (non-negative >= 0). It has been determined through the findings that the optimal number of clusters is three, with a DBI value of 0.3819.

## 5. Discussion

Relying on spatial Fuzzy C-Means clustering successfully identified interesting patterns and represented knowledge based on interestingness measures (Sankar & Bhuvaneswari, 2017). This was done to evaluate the potential of smart tourism in the Kemang Sub-district. A map of the possibilities for smart tourism that stakeholders can utilise to develop villages has now been completed. The spatial-based clustering integrated through the conditions of micro, small, and medium-sized enterprises (MSME) affiliated with local wisdom, physical and non-physical amenities in each village, and expert evaluation is called smart tourism potential. Because they have the highest readiness in infrastructure access, technology, and information and communication technology (Tosida et al., 2017, Tosida et al., 2018), as well as contact with stakeholders and business capital (Nugroho & Lestari, 2023), Kemang and Atangsanjaya villages have a very high potential to be transformed into smart tourism. The fact that Kemang Village and Atangsanjaya are close to the West Java provincial route lends credence to the abovementioned condition. Since 2018, Kemang Village has been making significant progress in the construction of high-end homes, which also helps to boost the potential for the growth of intelligent tourism. Atangsanjaya Village, a portion of the region that the Republic of Indonesia Air Force occupies, possesses a noteworthy degree of singularity. By integrating the flight school facilities that the Republic of Indonesia Air Force controls into stadiums and tourism attractions, this potential can be worked on with high information and communication technology (ICT) power (virtual reality technology, augmented reality, Internet of Things, artificial intelligence, and big data) (Trinanda, 2020). Tegal Village represents the third possible resource for smart tourism.

Even though Tegal Village still has an IDM in the development process, the village has significant potential to be developed into a smart tourism destination. In terms of preserving indigenous knowledge, creativity, invention, and interaction with many stakeholders, Tegal Village possesses a high level of competencies. Tegal Village is one of the villages that has been predicted to have the potential to become a smart village (Tosida, Setiawan, et al., 2023). This demonstrates that the potential of smart villages in Tegal Village is supported by citizen science mechanisms derived from local wisdom-based micro-enterprises (Tosida, Andria, et al., 2022). Tegal Village, which relied on local wisdom-based micro-enterprises, was second in the Women's Role Improvement Programme towards Healthy Family Welfare (P2WKSS) in West Java Province in 2020. The total number of micro-enterprises in Tegal Village was 340. Handicrafts and culinary specialities account for sixty-five percent of the revenue generated by these micro-enterprises. An establishment known as Kampung Batik New Normal Bogor has been operating in Tegal Village since December 2021. At present, there are two groups of batik craftsmen capable of producing thirty pieces of fabric every month. The Tegal-Kemang (TeMang Munggaran) and Tegal-Kemang (TeMang Raharja) motifs are already present in Tegal Village, making them something that sets it apart from other villages. Although Pakuan University has copyrighted these motifs, the inhabitants of Tegal Kemang Bogor are permitted to use them in conjunction with Pakuan University without restriction.

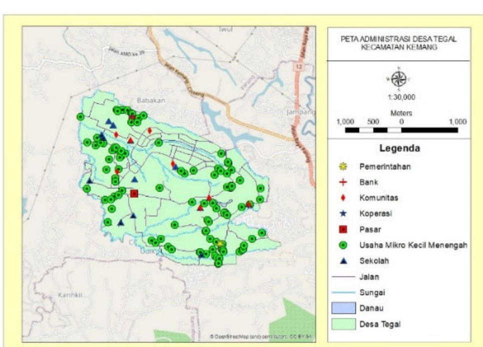



**Fig. 14.** Social facilities in Tegal Village

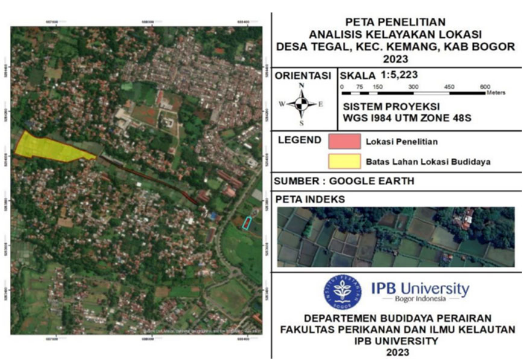



**Fig. 15**. BBIH Plan in Tegal Village

The village of Tegal has a flat topography and is located about 16 km away from the centre of Bogor. Moreover, twenty-five percent of the people living in Tegal Village are employed as fish breeding farmers. This community has a strong potential to be developed into a tourist village, as evidenced by the layout of the economic and social supporting components in the Tegal community. Figure 14 depicts the layout of Tegal Village, which was designed based on the characteristics that promote citizen science activities as a future smart village (Tosida, Herdiyeni, et al., 2022). The Bogor Regency Government plans to construct an Ornamental Fish Seed Centre (BBIH) in this village to cover an area of three hectares in 2025. A fish enlargement segment cultivation will be constructed at the BBIH in addition to the decorative fish nursery pond already intended to be constructed there. Figure 15 depicts the location of the BBIH in its current position. The findings of the water quality test indicate that it is ideal for fish enlargement cultivation; thus, this further improves Tegal Village's ability to improve the economy. This contributes to the possibility that the Tegal community could be transformed into a tourist community in the future. There is the possibility that edutourism could be formed from village tourism that is supported by activities related to citizen science. The presence of batik villages, micro business operations based on local wisdom, and the activities of people who work as fish breeders, particularly with the backing of the BBIH development plan, all contribute to this potential being highly suitable. By implementing the smart village ecosystem, it is anticipated that this potential will increase the Village Original Income (PAD), which will further encourage the development of Tegal Village into a village that possesses an advanced and even independent Village Development Index (IDM) level. Additionally, this potential will help the village achieve its Sustainable Development Goals (SDGs).

## 6. Conclusion

This study concludes that a total of 109 members of the first cluster are classified as having a moderate potential, 85 members of the second cluster are classified as having a potential cluster, and 105 members of the third cluster are classified as a high potential. These findings are based on research conducted using the Fuzzy C-Means algorithm to analyse the potential of smart tourism. The final results of the spatial-based cluster suggest that Kemang Village and Atangsanjaya are the clusters with great potential to develop into smart tourism. The villages of Tegal, Pondokudik, and Parakanjaya are the three clusters that have the potential to be turned into smart tourism. Specifically, Jampang, Pabuaran, and Bojong are the three villages with clusters that have significant potential to develop into smart tourism. Based on the results of the cluster evaluation using the Davie Boulding Index (DBI), the value obtained was 0.3819, and the optimal number of clusters was 3. Villages that are part of clusters with a strong potential to develop into smart tourism have high capacities in terms of access to infrastructure, technology, information and communication technology (ICT), engagement with stakeholders, and financing for businesses. Clusters that have the potential to become smart tourism have high capacities for the sustainability of local wisdom, creativity, innovation, and interaction with stakeholders. It is anticipated that the findings of this investigation will furnish novel understandings regarding the application of cluster evaluation strategies. It is possible to utilise it to find the most suitable method for producing the ideal amount of clusters. For the purpose of achieving smart villages, the knowledge pattern generated through spatial-based clustering using the Fuzzy C-Means algorithm can provide a reference for stakeholders involved in the planning of sustainable village development leading up to the Sustainable Development Goals for villages.

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