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Analysis of Characteristics of Earthquake Area in Indonesia in 2020 with Cluster Analysis as Natural Disaster

Bambang Avip Priatna Martadiputra[1], Dewi Rachmatin[2], Asep Syarif Hidayat[3]

[1]Mathematics Education Study Program, Indonesia University of Education, Dr. Setiabudhi 229, Bandung, 40154, West Java, Indonesia
[1]bambangavip[at]upi.edu

[2, 3]Mathematics Education Study Program, Indonesia University of Education
[2]dewirachmatin[at]upi.edu
[3]hasyhi[at]upi.edu

Abstract: ***This study aims to make maps and analyze the characteristics of earthquake areas in Indonesia in 2020. This study includes applied study in the field of statistics which applies cluster analysis to make maps and analyze the characteristics of earthquake areas in Indonesia in 2020. Making maps of earthquake areas is carried out with ArcGIS software help, while the analysis of characteristics of earthquake area is carried out using cluster analysis (k-medoids method) with R software help. The results show that during 2020, almost all areas in the Indonesian Archipelago are prone to earthquakes, except for areas in Kalimantan Island that are relatively safe from earthquakes. Most of the earthquake spots come from Maluku, Sulawesi, and Papua islands. The 2020 earthquakes are grouped into 9 clusters. The first, second, third, fourth, fifth, sixth, and seventh clusters are shallow earthquakes seen from the median depth of the earthquake which is less than 70 km. The eighth cluster includes intermediate earthquakes seen from the median depth of the earthquake reaching 143 km, while the ninth cluster includes deep earthquakes seen from the median depth of the earthquake reaching 631 km. This means that shallow earthquakes still dominate in 2020. The earthquake area which is included in the third cluster is an area that needs to be watched out for the frequency of the earthquake is higher than other areas.***

Keywords: cluster analysis; k-medoids method

1. Introduction

Indonesia is located on two earthquake routes in the world, namely: the circum-Pacific route and the Himalayan-Mediterranean route. Besides, Indonesia has 3 tectonic plates, namely: the Pacific, Indo-Australian, and Eurasian plates. In Indonesia, there are many active faults such as Semangko Fault in Sumatra, Cimandiri Fault in Java, and many other faults and sub-faults scattered all over Indonesia [Sugito, 2008].

The earthquake and tsunami measuring 9.1 on the Richter Scale (RS) in Aceh in 2004 caused a major catastrophe in the north of Sumatra Island to South Asia and Africa, causing more than two hundred thousand lives. After the 2004 Aceh earthquake and tsunami, the Indonesian society and government increased concern for the disasters. This concern was not only about earthquakes but also several other disasters, such as volcanic eruptions, landslides, and floods. This concern was manifested by the enactment of Law 24 of 2007 concerning Disaster Management and the establishment of the National Disaster Management Agency (Badan Nasional Penanggulangan Bencana, BNPB) as part of the implementation of the mandate of this law [BNPB, 2007].

The National Disaster Management Agency has prepared a National Long-Term Development Plan (Rencana Pembangunan Jangka Panjang Nasional, RPJPN) for 2005 to 2025. This RPJPN is an elaboration of the 1945 Constitution which pays great attention to disaster management efforts. The RPJPN is formulated with the basic consideration that the general condition of the Indonesian country is in a disaster-prone area with 8 (eight) national development missions, including the seventh mission, "To make Indonesia an independent, advanced, strong archipelago and based on national interests. Reducing the impact of coastal disasters and marine pollution is carried out through (a) developing a disaster mitigation system, (b) developing an early warning system, (c) developing a national plan for an emergency response to oil spills at sea" [BNPB, 2007].

During 2018, there were 23 destructive earthquakes and 3 tsunamis. As many as 19 of the 23 destructive earthquakes were earthquakes triggered by active faults, the rest were due to subduction or submergence of continental plates. Among the three tsunamis that occurred, the largest tsunami during 2018 occurred in Donggala Palu (Central Sulawesi) on 28 September which resulted in 2,037 people died, 4,084 people injured, 671 people missing, 74,044 people displaced, 67,310 houses damaged, and buildings of worship facilities/health facilities/infrastructure/offices were damaged [BMKG, 2018].

The Meteorology, Climatology, and Geophysics Agency (Badan Meteorologi Klimatologi dan Geofisika, BMKG) recorded 17 earthquakes that caused damage to houses throughout 2019. Overall seismic activity in Indonesia this year occurred 11,573 times, in which most or as much as 11,229 times were dominated by earthquakes of less than 5 RS [Agustine, 2019].

The following is a large earthquake that has shaken areas in Indonesia and caused death tolls throughout 2019: (1) An earthquake with a magnitude of 7.2 in Halmahera Regency on 14 July 2019, destroyed many infrastructures and damaged dozens of buildings, and damaged people's houses by the earthquake reaching 2,779 units, and the victims who died were 13 people; (2) An earthquake with a magnitude of 6.8 in Ambon. An earthquake with a magnitude of 6.8 (updated to 6.5 magnitudes) occurred in Ambon Island and West Seram Regency on 26 September 2019 at around 08.46 WIT. This shallow earthquake left 30 people died and 156 people injured; and 3) A megathrust earthquake with a magnitude of 6.9 RS in Banten caused 6 people died and 3 people injured [Wismabrata, et.al., 2019].

The various earthquake disasters in Indonesia that have been described above have resulted in many casualties, material loss, and infrastructure damage which have impacts on the socio-economy of society, economic growth, as well as swelling budgets that the Indonesian government must allocate. This fact is the background for researchers conducting a study to make maps and analyze the characteristics of earthquake areas in Indonesia in 2020. The results of this study are expected to contribute to policymakers in planning and implementing earthquake disaster mitigation that may occur in the future.

2. Literature Review

2.1. Study Literature

Along with the development of times and technology, at this time, data on events and study results on human earthquakes are available in a very large amount (big data) stored in cyberspace and can be accessed by anyone in this world. This is because there are various data so researchers must be able to extract data into a simpler data set called *data mining*. *Data mining* is computer science which has the goal of extracting information from data sets and converting that information into new understandable information structures for further use. The patterns or trends of the data set can be analyzed, and the results of this analysis will be useful for future decision making. There are several methods used in *data mining* such as *classification*, *clustering*, *association*, and others [Sensuk, et.al., 2019].

Senduk, et. al. (2019) conducted a study on earthquakes by applying the *k-medoids method* which is *robust* to outliers. The results showed that for the latest earthquake data for 2014-2019, 6 clusters were obtained, in which cluster 3 was the most earthquake-prone area with the following characteristics: (1) having an average depth of below 70 Km (shallow earthquake); (2) the highest average magnitude compared to other clusters, i.e. 5,337354 RS (Richter Scale). The highest number of earthquakes occurred during 2019. In the Maluku Islands, there were 98 out of 297 earthquakes recorded by researchers [Rachmatin and Sawitri, 2019]. The North Sulawesi region during 2019 experienced 41 earthquakes with earthquake magnitude of more than 5 RS. To the east of the Maluku Islands, namely the Papua area, 36 earthquakes occurred during 2019 with earthquake magnitude of more than 5 RS [Rachmatin and Sawitri, 2019].

2.2. Theoretical Framework

2.2.1. Earthquake

Earthquake is the original vibrations from within the earth that originate in the earth and then propagate to the earth's surface, which is caused by the cracks of the earth breaking and shifting violently. The causes of earthquakes can be in the form of earth dynamics (tectonics), volcanic activity, a meteor falls, avalanches (below sea level), or the explosion of nuclear bombs below the surface of the land/sea [Nur, 2010].

The tectonic earthquake is the most common in the form of vibrations generated because the rock debris due to the collision of two plates will slowly result in the accumulation of impact energy that exceeds the strength of the rock so that the rocks below the surface fracture [Nur, 2010]. Oceanic plates whose mass density is greater when colliding with continental plates in the collision (subduction) zone will creep downward. The plate movement will experience a slowdown due to friction from the earth's casing. The slowdown in motion causes a buildup of energy in the subduction and fault zones. As a result, pressure, pull and friction occur in these zones. When the limit of plate elasticity is exceeded, a rock fracture occurs followed by a sudden release of energy. This process causes the particles to vibrate in all directions, which is called an earthquake wave [BMKG, 2018].

2.2.2. Cluster Analysis

Cluster analysis aims to allocate a group of individuals to groups that are independent of each other so that each individual in the same group will be similar to one another, while the individuals in different groups are not similar. In grouping, a measure of similarity or closeness between data is used to explain the simple group structure of complex data, such as a measure of distance or similarity, and a measure of distance called *Euclid's distance* [Johnsons and Wincern, 1982].

There are two methods in cluster analysis, namely: 1) *hierarchical method* and 2) *non-hierarchical method*. *The hierarchical method* is divided into two, namely *the agglomerative* (concentration) method and *the divisive (dispersion) method*. In *the hierarchical method*, the number of groups to be obtained is unknown, while in *the non-hierarchical method*, it is assumed that there are *k* groups first. The methods included in *the agglomerative method* are *single linkage method*, *complete linkage method*, *average linkage method*, *Ward's method*, *centroid method*, and *median method* [Everitt, 1974]. Meanwhile, *the non-hierarchical method* includes the *k-means method*, *k-medoids method*, and *fuzzy method*.

K-Medoids or *Partitioning Around Medoids* (PAM) is a clustering algorithm similar to *k-means*. The *k-medoids algorithm* was developed in 1987 by Kaufmann and Rousseeuw [Kaufmann, 2005]. The *k-medoids* or PAM algorithm uses the object as the representative (*medoid*) as the cluster center for each cluster, while the *k-means algorithm* uses the average (mean) value as the cluster center. The *k-medoids* algorithm has the advantage of overcoming weaknesses in the *k-means algorithm* which is sensitive to outliers ([Arora, et.al., 2016], [Kaufmann, 2005]).

The basic strategy of the *k-medoids clustering algorithm* is to find *k* (the number of clusters) in *n* object to firstly find the representative object for each cluster. The objects that represent each cluster are called *medoids*. Clusters are built by calculating the proximity between the *medoid* and *non-medoid objects* using the *Manhattan distance*. Every object that is not a *medoid* is grouped into groups with *the medoid* closest to itself. After initialization of random *initial medoid* selection, the algorithm is repeated to find a better choice of other *medoids* ([Setiyawati, 2017],[Sihombing, et. al., 2019]).

In conducting the *clustering* process (*cluster analysis*), several assumptions must be fulfilled by the data. The assumptions in *cluster analysis* are that the data must be free from outliers and *multicollinearity*. In fact, not all data meet these two assumptions, such as the earthquake area data that contains outliers. To solve the outliers problem, there is *a non-hierarchical cluster analysis method* that is resistant to outliers, i.e. *k-medoids* [Soni and Patel, 2017].

Many studies using *k-means* have been conducted such as studies conducted by Kamat & Kamath (2016), and Savas et. al. (2019). However, according to a study by Soni & Patel (2017) comparing the *k-means* and *k-medoids algorithms*, *k-medoids* are more efficient than *k-means* ([Senduk, et. al., 2019] & [Soni and Patel, 2017]. Therefore, in this study, *a cluster analysis* approach will be used with *the k-medoids method* (see [Rachmatin and Sawitri, 2020], [Setiyawati, 2017] & [Sihombing, et.al., 2019]) to see the characteristics of the results of grouping earthquake data in Indonesia in 2020.

3. Study Method

K-Medoids or *Partitioning Around Medoids* (PAM) is a clustering algorithm similar to *k-means*. This study includes applied research [Kothari, 2004] in the field of statistics using a quantitative approach [Creswel and Creswel, 2018] which applies cluster analysis to make maps and analyze the characteristics of earthquake areas in Indonesia in 2020. The study data is obtained by a documentary study using an instrument in the form of an observation sheet containing data on the time of the event (date and time); epicenter position (longitude and latitude), strength (magnitude), and depth; and the epicenter of earthquakes that have occurred in Indonesia.

The data processed in this study are earthquake data in Indonesia in the period of 1 January 2020 to 19 October 2020. Making earthquake area maps is carried out with the help of ArcGIS version 10.8.1 software, while the analysis of earthquake area characteristics is carried out using *cluster analysis* (*k-medoids method*) with the R software. The results are mapped with ArcGIS software to obtain the distribution of earthquake areas in Indonesia in 2020 and their characteristics.

4. Results and Discussion

The data processed in this study are earthquake data in Indonesia in 2020 obtained from the official BMKG website, namely https://bmkg.go.id [5]. This data is a combination of the latest earthquake data (earthquakes with a magnitude of ≥ 5 RS) with earthquake data that is felt (earthquake data with a magnitude of more than 5 RS or a magnitude of fewer than 5 RS). Earthquake data that the researchers collect consist of 654 observations, which are scattered throughout Indonesia and recorded from 1 January 2020 to 19 October 2020. The variables involved such as longitude, latitude, magnitude, and depth in the case study of this study are not correlated. The following is a summary of the descriptive statistics for earthquake data (earthquake data from 1 January to 19 October 2020).

Table 1: Descriptive statistics of earthquake data in Indonesia
(Period of 1 January to 19 October 2020)

	Longitude	Latitude	Depth	Magnitude
Minimum	93.49	-11.630	1	1.040
1st Quantile	110.78	-7.808	10	3.050
Median	120.41	-3.570	10	4.030
Mean	119.11	-3.814	32.3	3.957
3rd Quantile	128.14	-1.242	23	5
Maximum	147.70	12.070	664	7.300

From Table 1, it can be seen that the smallest magnitude is 1.04 RS (Richter Scale) and the biggest magnitude is 7.3 RS with an average earthquake magnitude of 3.957 RS. The minimum earthquake depth is 1 Km and the median is 10 Km below sea level, while the maximum earthquake depth that occurs is 664 Km below sea level.

Before the earthquake data for 2020 being processed with cluster analysis, a map of the distribution of the earthquake disaster areas must first be made using ArcGIS version 10.8.1 software. The results are shown in Figure 1 to the following Figure.

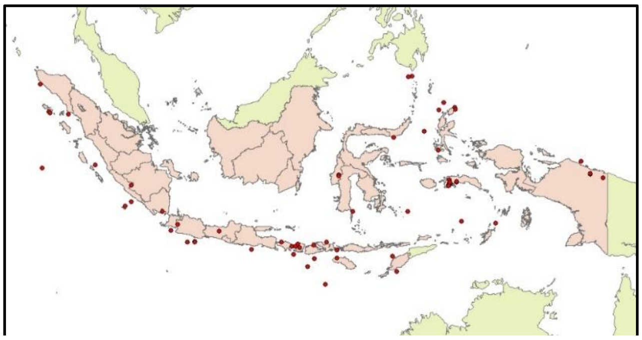

Figure 1: Distribution map of earthquake disaster in January 2020

The map of the distribution of earthquakes for January 2020 shows that earthquake disasters are spread across all islands in Indonesia, except for the Kalimantan island. The earthquakes that occurred during January were dominated by shallow earthquakes with a depth of 0-70 Km below sea level. The Kairatu area of West Seram Regency was recorded to have experienced five earthquakes during January 2020 with the largest earthquake magnitude reaching 3.03 RS with a depth of 10-16 Km. Meanwhile, the southwestern area of southern Nias was recorded as the largest earthquake with a magnitude of 10 RS with a depth of 5.02 Km below sea level, this earthquake occurred on 5 January 2020, at 06:42:47 WIB.

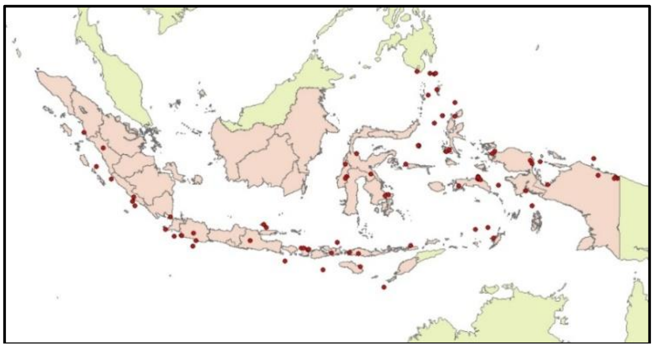

Figure 2: Distribution map of earthquake disaster area in February 2020

From Figure 2 shows that during February 2020, earthquake disasters were scattered throughout the Indonesian archipelago. The earthquakes that occurred during February were still dominated by shallow earthquakes. Of the 83 earthquakes that occurred during February 2020, the most destructive earthquake was the earthquake with a magnitude of 6.07 RS which occurred in 56 Km Northwest of West Southeast Maluku on 26 February 2020 at 14:33:12 WIB, with an earthquake depth of 28 km. From Figures 1 and 2, it can be seen that the distribution map of earthquake spots is more prevalent in the Maluku Islands, Papua, Sulawesi, and Lombok areas.

Before being analyzed using the *k-medoids method*, earthquake data normalization is carried out with the *scale* function using the R software. The results of data processing using the *k-medoids method* with the help of the R version 3.5.3 program with the *factoextra package* and *cluster package* show that there are nine clusters with an *average silhouette coefficient* is equal to 0.3537662 (see Figure 3).

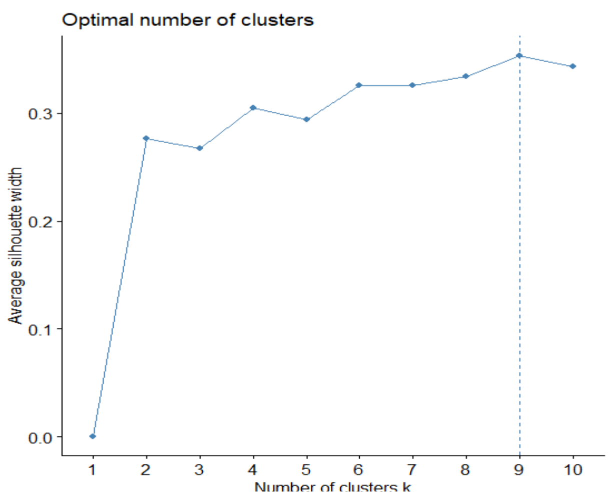

Figure 3: *Average silhouette coefficient plot* for *k-medoids method* for various *k*.

Descriptive statistics for nine clusters can be seen in Table 2 to Table 10.

Table 2: Descriptive statistics for the 1st cluster

	Longitude	Latitude	Depth	Magnitude
Mean	126,5692	-2,8006	11,0677	2,6947
Median	128,26	-3,32	10	3,02
Maximum	140,75	2,07	100	3,4
Minimum	118,92	-4,68	2	1,09
Standard Deviation	5,7229	1,256	9,0572	0,4931

Table 3: Descriptive statistics for the 2nd cluster

	Longitude	Latitude	Depth	Magnitude
Mean	129,7218	-2,653	14,3737	4,3237
median	129,9	-2,76	10	4,05
Maximum	140,93	1,1	75	5,5
Minimum	107,7	-7,26	3	3,04
Standard Deviation	7,1148	1,4673	11,4085	0,4911

Table 4: Descriptive statistics for the 3rd cluster

	Longitude	Latitude	Depth	Magnitude
Mean	126,1565	2,0918	35,2289	5,0191
Median	126,47	1,87	10	5,02
Maximum	139,64	12,07	196	7,01
Minimum	117,39	-4,15	8	3,01
Standard Deviation	2,8771	2,5849	42,2802	0,7026

Table 5: Descriptive statistics for the 4th cluster

	Longitude	Latitude	Depth	Magnitude
Mean	115,8578	-9,0268	25,4369	4,4471
Median	116,26	-8,99	10	4,08
Maximum	125,62	-5,71	119	6,06
Minimum	107,27	-11,63	10	4
Standard Deviation	4,5129	1,0093	26,3973	0,5282

Table 6: Descriptive statistics for the 5th cluster

	Longitude	Latitude	Depth	Magnitude
Mean	96,9893	3,4601	21,6667	4,0604
median	96,12	3,85	10	4,05
Maximum	112,51	8,82	125	6,04
Minimum	93,49	-0,78	3	3
Standard Deviation	2,9905	2,3124	28,0495	0,8282

Table 7: Descriptive statistics for the 6th cluster

	Longitude	Latitude	Depth	Magnitude
Mean	113,8217	-8,0585	14,3614	2,824
Median	114,99	-8,3	10	3,03
Maximum	125,08	-5,87	91	3,1
Minimum	105,75	-9,76	1	1,04
Standard Deviation	5,5067	0,7849	15,3739	0,4344

Table 8: Descriptive statistics for the 7th cluster

	Longitude	Latitude	Depth	Magnitude
Mean	103,099	-5,0355	26,8907	4,5095
Median	102,83	-4,96	21	4,08
Maximum	108,24	-0,93	135	10
Minimum	95,68	-7,89	2	3,03
Standard Deviation	2,4911	1,9169	25,7262	0,988

Table 9: Descriptive statistics for the 8th cluster

	Longitude	Latitude	Depth	Magnitude
Mean	129,2046	-6,6579	152,25	5,1375
Median	129,655	-6,86	143	5,025
Maximum	141,41	0,2201	321	7,03
Minimum	118,161	-9,27	28	4,05
Standard Deviation	4,8122	1,7805	57,6757	0,7211

Table 10: Descriptive statistics for the 9th cluster

	Longitude	Latitude	Depth	Magnitude
Mean	118,8043	-5,3643	615,571	5,4443
Median	120,53	-6,92	631	5,05
Maximum	124,19	3,93	664	6,03
Minimum	110,55	-7,4	553	5
Standard Deviation	5,4018	4,1272	39,9118	0,5326

From Table 2 to Table 8, it is known that earthquakes included in the 1st to the 7th cluster are shallow earthquakes with a depth of 0-70 Km and moderate earthquakes with a depth of 70-300 Km. Meanwhile, earthquakes included in the 8th cluster are all shallow earthquakes with a magnitude of ≥ 28 Km, moderate earthquakes, and deep earthquakes with a depth of 300-321 Km (see Table 9). Meanwhile, earthquakes included in the 9th cluster are unique (see Table 10) because earthquakes included are only the deep earthquakes (earthquakes with a depth of more than 300 Km) with a magnitude ranging from 5.00-6.03 RS.

From Table 2 to Table 10, it is known that each cluster has different or unique characteristics. For example, in Table 5 and Table 8, the two clusters have the same median magnitude of 4.08 RS, but the maximum magnitude of the 7th cluster is 10 RS greater than the maximum magnitude of the 4th cluster which is 6.06 RS. From Table 4, it is known that the 3rd cluster has similarities in the median magnitude and maximum magnitude to the 8th cluster, but the maximum depth of the 3rd cluster earthquake is 196 Km smaller than the maximum depth of the 8th cluster earthquake which is 321 Km.

When viewed from the median depth of earthquakes throughout 2020, the nine earthquake clusters have different earthquake types. The first, second, third, fourth, fifth, sixth, and seventh clusters include shallow earthquakes with a median earthquake depth of fewer than 70 Km. The eighth cluster includes moderate earthquakes with a median earthquake depth of 143 Km, while the ninth cluster includes earthquakes with a median depth of earthquakes reaching 631 Km.

Clusters 1 to 8 have a risk level for earthquake-prone areas between 2-3 on the MMI scale, and only a few events have a risk level with a scale IV and scale V. Most of the earthquakes included in this cluster have a very low-risk level, meaning that this area is an area that experiences light shaking, and there are only a few areas that experience minor shocks and damage and have fractured buildings and experience movement in the ground.

The ninth cluster has a very low-risk level because the area in the ninth cluster has an MMI scale between 2 to 3, which means that this area only experiences light shaking. Note that this ninth cluster is a cluster that has a characteristic of earthquake depth between 553 Km to 664 Km, so it is reasonable if the earthquake magnitude felt is only light shaking because the epicenter is far below sea level.

The plot of the nine clusters obtained by the *k-medoids method* shows that the nine clusters are quite separate in Figure 4. The ninth has very different characteristics from other clusters, from the plot, it can be seen that the earthquake group in the ninth cluster is quite far apart from other clusters.

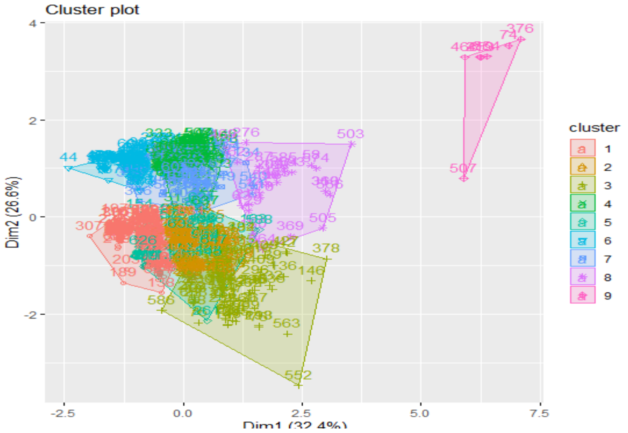

Figure 4: Plot of nine clusters obtained with *k-medoids*.

The grouping results using the *k-medoids method* obtain 9 clusters. Next, a distribution map of earthquake-prone areas is made for the nine clusters with the help of ArcGIS 10.8.1 software. The mapping results can be seen in Figure 5 to Figure 13.

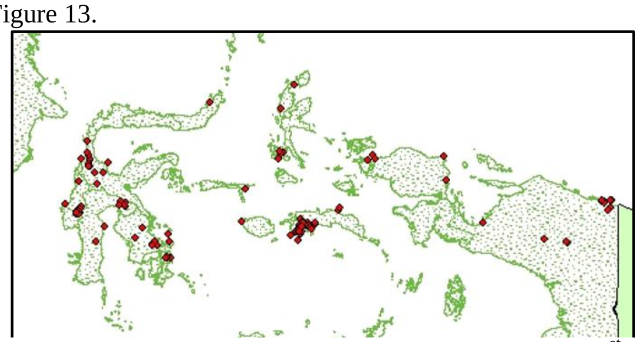

Figure 5: Distribution map of earthquake areas for the 1st cluster

From Figure 5, it can be seen that the 1st cluster earthquakes cover several areas on the Sulawesi Island, the Maluku Islands, and the Papua Island. The areas on the Sulawesi Island are the largest areas included in the 1st cluster with a magnitude ranging from 1.09-3.4 RS (see Table 2).

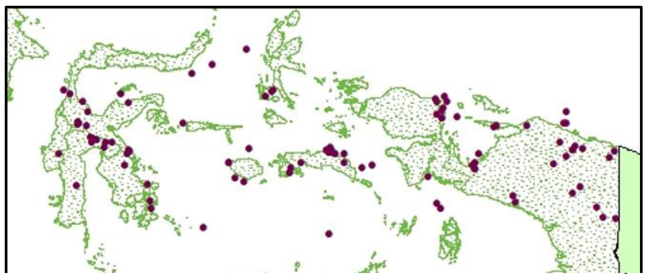

Figure 6: Distribution map of earthquake areas for the 2nd cluster

From Figure 6, it can be seen that the 2nd cluster earthquakes cover some on the Sulawesi Island, the Maluku Island, and the Papua Island. The areas in Papua are the most earthquake areas included in the 2nd cluster with a magnitude of 3.4-5.5 RS (see Table 3).

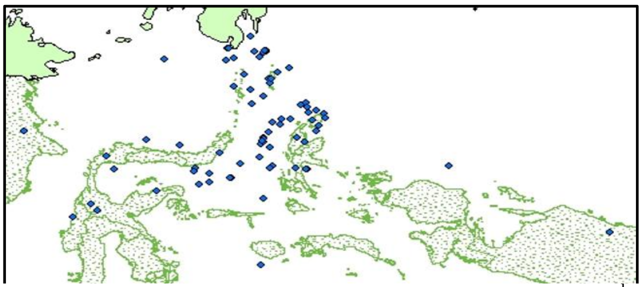

Figure 7: Distribution map of earthquake areas for the 3rd cluster

From Figure 7, it can be seen that the 3rd cluster earthquakes cover several areas on the Sulawesi Island, the Maluku Islands, and the Papua Island. The areas in the Maluku Islands are the most earthquake areas included in the 3rd cluster with a magnitude of 3.01-7.01 RS (see Table 4).

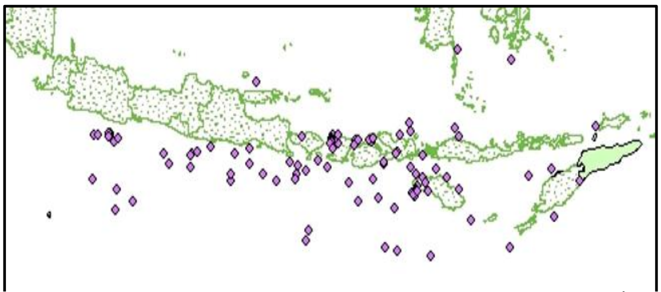

Figure 8: Distribution map of earthquake areas for the 4th cluster

From Figure 8, it can be seen that the 4th cluster earthquakes cover several areas on the Java Island, Bali Island, Lombok Island, West Nusa Tenggara and East Nusa Tenggara. The earthquakes that occurred are scattered along the south coast of those islands with the types of shallow and medium earthquakes with a magnitude of 4.00-6.06 RS (see Table 5).

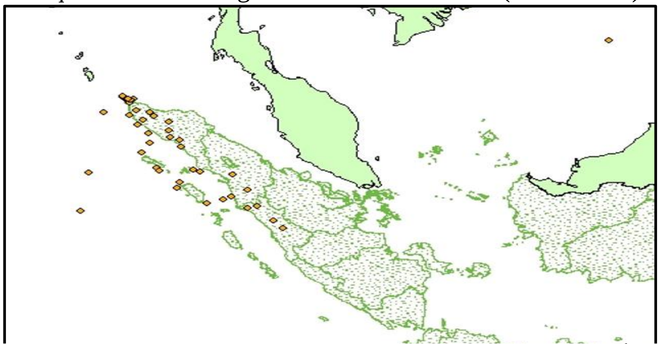

Figure 9: Distribution map of earthquake areas for the 5th cluster

From Figure 9, it can be seen that the 5th cluster earthquakes cover several areas on the Sumatra Island, i.e. Aceh, North Sumatra, West Sumatra, and Bengkulu. The earthquakes that occurred include shallow and moderate earthquakes with a magnitude of 3.00-6.04 RS (see Table 6).

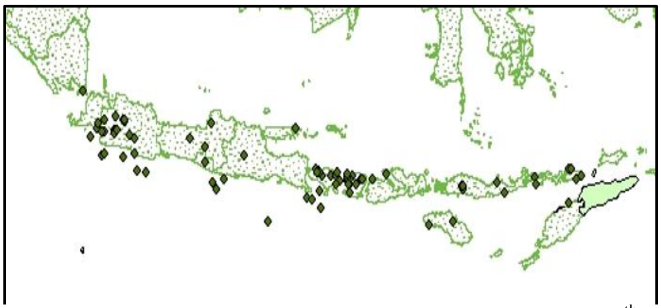

Figure 10: Distribution map of earthquake areas for the 6th cluster

From Figure 10, it can be seen that the 6th cluster earthquakes cover several areas on Java Island, Bali Island, Lombok Island, West Nusa Tenggara Island, and East Nusa Tenggara Island. The earthquakes that occurred were scattered along with those islands, and only a few were scattered along the southern coast of those islands which included shallow and moderate earthquakes with magnitudes of 1.04-3.1 RS (see Table 7).

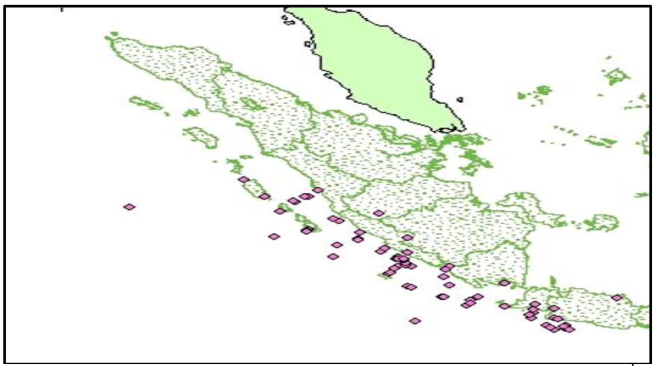

Figure 11: Distribution map of earthquake areas for the 7th cluster

From Figure 11, it can be seen that the 7th cluster earthquakes cover several areas along the western coast of the Sumatra Island, Banten province, and the southern area of West Java which includes shallow and moderate earthquakes, with a magnitude of 3.03-10.00 RS (see Table 8).

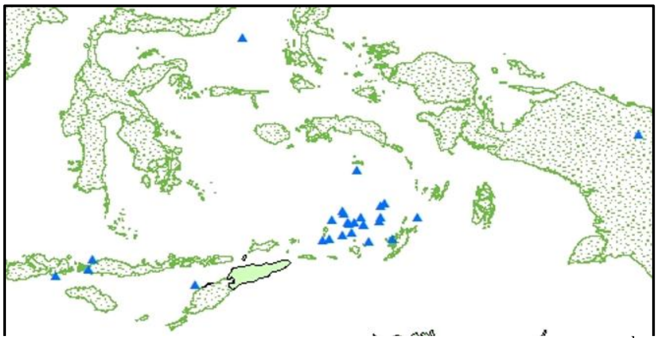

Figure 12: Distribution map of earthquake areas for the 8th cluster

From Figure 12, it can be seen that the 8th cluster earthquakes cover several areas of Kupang, Maluku islands, Papua, and North Sulawesi areas which include shallow, moderate, and deep earthquakes with a magnitude of 4.05-7.03 RS (see Table 9).

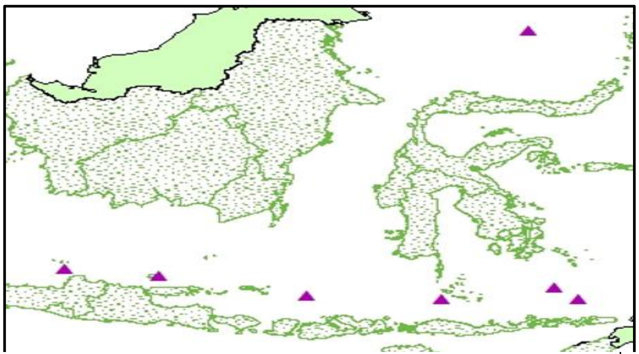

Figure 13: Distribution map of earthquake areas for the 9th cluster

From Figure 13, it can be seen that the 9th cluster earthquakes cover several areas in West Lampung, Bangkalan-Madura, Alor-NTT, Saringi-NTB, Jepara, Selayar-South Sulawesi, and the Sangihe Island-North Sulawesi which are included in the deep earthquake with a magnitude of 5.00-6.03 RS (see Table 10). The nine clusters obtained by the *k-medoids method* can be mapped again together in Figure 14.

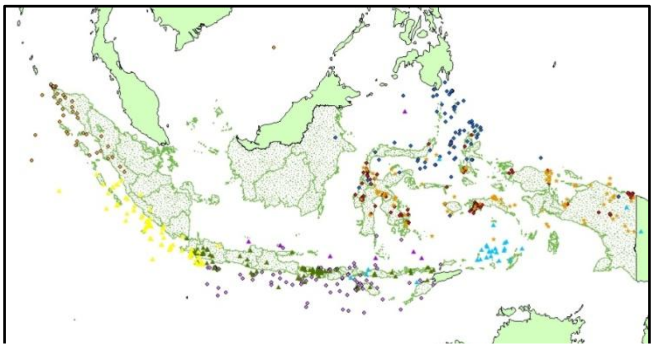

Figure 14: Distribution Map of Earthquake Areas in 2020 for Nine Clusters

From Figure 14, it can be seen that earthquakes occurred in almost all regions of Indonesia except on Kalimantan Island which was relatively safe from earthquakes during the period of 1 January 2020 to 19 October 2020. The same results have been shown in previous studies, Kalimantan Island, during 2019, was relatively safe from earthquake disasters [12].

The areas with the highest frequency of earthquakes during the period of 1 January 2020 to 19 October 2020 include: (1) Kairatu Area in West Seram Regency, precisely in the north of Ambon Island as many as 22 times; (2). The northern part of Lombok and the Melonguane Islands, North Sulawesi, experienced 19 earthquakes each; and (3). Daruba, North Maluku region, experienced earthquakes 18 times. In 2019, the Melonguane region of North Sulawesi was the area with the most earthquake frequency, which experienced 18 earthquakes.

The 3rd cluster has the largest median magnitude of the nine clusters, i.e. 5.02 RS with a median earthquake depth of 10 Km. Areas included in the 3rd cluster are areas in North Maluku, North Sulawesi, West Sulawesi, Central Sulawesi, North Halmahera, Pacitan East Java, and Jayapura area. The 3rd cluster needs attention because the earthquake frequency from the previous year (2019) is relatively more than other areas, and the earthquake magnitude is ≥ 3.01 RS.

Of the nine clusters, it is known that a relatively safe earthquake compared to other clusters is the 9th cluster which has an earthquake depth of more than 550 Km with an earthquake magnitude of ≥ 5 RS.

5. Conclusion

Based on the results of data analysis and its interpretation, it is concluded that :

1) From the 2020 map of the earthquake in Indonesia resulted, it is known that in 2020, earthquakes almost occur in all regions in Indonesia, except on Kalimantan Island. Most of the earthquake spots originate from Maluku Island, Sulawesi, and Papua.
2) Earthquakes in Indonesia in 2020 have the following characteristics:
3) In 2020, the earthquakes that occurred in Indonesia can be grouped into 9 clusters with distinctive characteristics.
4) Earthquakes in clusters 1 to 7 include shallow earthquakes with a median earthquake depth of fewer than 70 Km. The 8th cluster earthquakes include medium earthquakes with a median earthquake depth reaching 143 Km, while the 9th cluster includes deep earthquakes with a median earthquake depth reaching 631 Km. This shows that in 2020, earthquakes in Indonesia were dominated by shallow earthquakes.
5) During the period of 1 January 2020 to 19 October 2020, the risk level for earthquake-prone areas in Indonesia was a very low to low level, meaning that the disaster area has experienced light to moderate shocks with minor damage. Only a few areas experience building cracks and the ground movement.
6) Areas included in the 3rd cluster are areas to watch out for because the frequency of earthquakes is relatively more frequent than other areas with the largest median magnitude with a median earthquake depth of 10 Km which is a shallow earthquake. These areas should receive more attention than other areas in planning disaster mitigation due to earthquakes.

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