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The Natural Disaster Prone Index Map Model in Indonesia Using the Thiessen Polygon Method

Model Peta Indeks Rawan Bencana Alam di Indonesia Menggunakan Metode Polygon Thiessen

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Abstract— Natural Disasters are natural phenomena that occur at any moment that can cause loss. Indonesia is an archipelagic country located at the meeting of four tectonic plates and volcanic belts. This condition causes Indonesia to be prone to natural disasters. Therefore, it is necessary to make a natural disaster-prone index map model minimize the impact of natural disasters. In this research, the researchers used a Polygon Thiessen method for it was one of the mapping methods to determine a natural disaster based on Indonesia's vast surface and many disasters. The BNPB and Polygon Thiessen data comparison shows that BNPB data has a low level of vulnerability of 302, a moderate level of vulnerability of 148, and a high level of vulnerability of 58. In contrast, the Thiessen polygon has a low level of vulnerability of 297, a moderate vulnerability of 158, and a high vulnerability of 59. Comparing BNPB data and the Thiessen Polygon method found five differences from 40 data in the Papua region. Suggestions for further research to create an application-based information system so that it can be accessed in real-time.

Keyword— Polygon Thiessen, Indonesia, Natural Disaster, Mapping, System Information Geographic

Abstrak— *Bencana alam merupakan fenomena alam yang terjadi setiap saat yang dapat menimbulkan kerugian. Indonesia merupakan negara kepulauan yang terletak pada pertemuan empat lempeng tektonik dan sabuk vulkanik, sehingga kondisi ini menyebabkan Indonesia rawan bencana alam. Maka dari itu perlu dilakukan pembuatan model peta indeks rawan bencana alam agar memudahkan pihak yang membutuhkan untuk meminimalisir dampak bencana alam. Dalam penelitian ini, peneliti menggunakan metode Polygon Thiessen. Metode polygon thiessen dipilih karena merupakan salah satu metode pemetaan untuk menentukan klasifikasi bencana alam berdasarkan luas permukaan dan banyak bencana yang terjadi di Indonesia. Perbandingan data BNPB dan Polygon Thiessen didapatkan data BNPB memiliki tingkat kerawanan rendah sebanyak 302, tingkat kerawanan sedang sebanyak 148, dan tingkat kerawanan tinggi sebanyak 58 sedangkan polygon thiessen memiliki tingkat kerawanan rendah sebanyak 297, kerawanan sedang sebanyak 158, dan kerawanan tinggi sebanyak 59. Hasil perbandingan data BNPB dan metode Polygon Thiessen didapati 5 perbedaan dari 40 data pada wilayah Papua. Saran untuk penelitian selanjutnya membuat sistem informasi berbasis aplikasi sehingga dapat diakses secara real time.*

Kata Kunci— *Polygon Thiessen, Indonesia, Bencana Alam, Pemetaan, Sistem Informasi Geografis*

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I. INTRODUCTION

Natural disasters are one of the natural phenomena that occur at any time, which can cause material and immaterial losses to people's lives [1] Natural disasters in Indonesia show an increase and decrease every year, causing high levels of losses experienced by the community [2]. It is known from data from the National Disaster Management Agency (BNPB) for 13 years from 2007-2019 [3].

Indonesia is an archipelagic country that lies at the crossroads of four tectonic plates; Indonesia is also located on an elongated volcanic belt with each side in lowlands and old volcanic mountains. This condition can potentially cause natural disasters such as earthquakes, landslides, floods, and volcanic eruptions [4].

Geographical information related to natural disasters is needed in making plans for disaster mitigation. Making the natural disaster spatial map is needed because people can directly see the condition of disaster-prone areas. After all, most of the data is only in the recap into figures that show the percentage of natural disasters. Based on this, it is necessary to make a model map of the index of natural disaster hazards in Indonesia to find out each region in Indonesia with high, moderate, and low levels of vulnerability.

Some research [5]–[11] made a multi-disaster mapping using the overlay method and weighting the parameters of natural disasters taken only floods, tidal floods, landslides, and droughts to obtain high, moderate, and low vulnerability levels. The overlay method is merging natural disaster data in an overlapping manner to produce a new map so that it does not divide disaster-prone areas in detail and natural disaster data that makes the map made less accurate. Therefore, researchers use other methods to group multi-disaster areas, namely the Thiessen polygon method, and also add natural disasters that occur to increase the accuracy of the classification of natural disasters that occur. This method is one of the mapping methods to determine the distribution of natural disasters in an area based on surface area and the number of disasters in Indonesia.

Thiessen polygon, also known as Voronoi Diagram, is a partitioning of n planes with points into polygons. Each polygon has precisely one generating point, and each point in that polygon is closer to that generating point than any other point in the polygon [12].

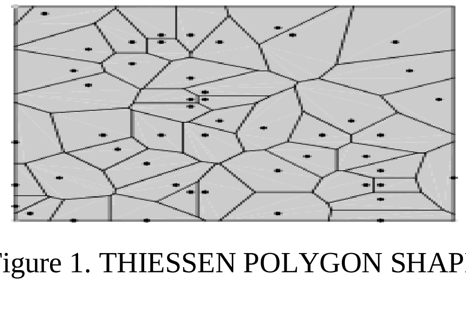

Figure 1. THIESSEN POLYGON SHAPE

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To create a polygon, first, make a network at specific points that form a polygon pattern in dividing the area based on the nearest area. If there is a change in the nearest regional network, like the addition of an area, a new polygon must be created [13].

This study aims to classify the level of natural disasters in Indonesia from 2007-2019 into groups of appropriate natural disasters based on natural disasters that occurred in Indonesia using the Thiessen polygon method. The researcher chose the Thiessen polygon method because it is one of the mapping methods to determine the distribution of natural disasters in an area based on surface area and the number of disasters in Indonesia. The hope of this research can be a reference for the community, regency/city governments, or organizations dealing with natural disasters to pay more attention to decisions taken in tackling natural disasters appropriately so that it can minimize the impact of natural disasters in the future.

II. RESEARCH METHOD

This study implemented the Thiessen polygon algorithm to generate an index model for disaster-prone maps in Indonesia. This study used a quantitative method approach with secondary data obtained from BNPB because the obtained data are only in numbers and without manipulation or changes to achieve research objectives. The following Figure 2 illustrates the stages of the research.

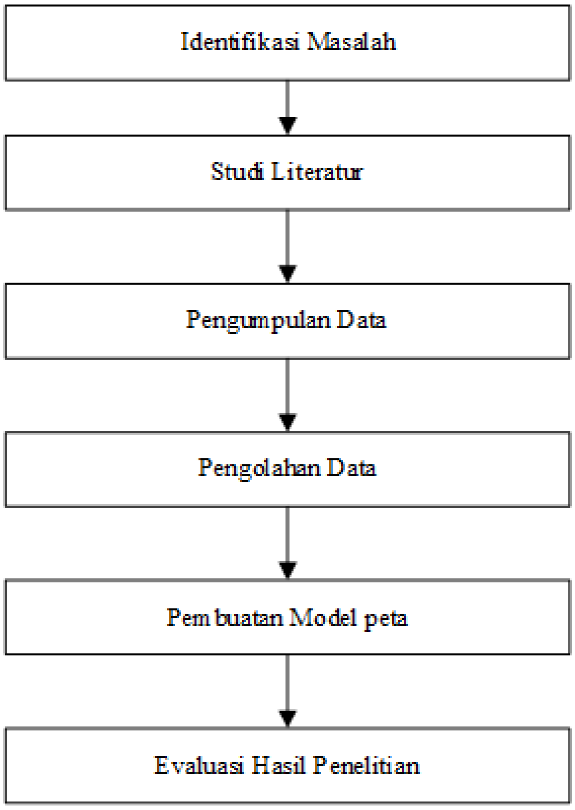

Figure 2. RESEARCH METHODOLOGY

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This study conducted a mapping of natural disasters because the public can directly see the condition of disaster-prone areas. Most of the existing data are in the form of numbers showing the percentage of natural disasters. Several studies were carried out to map the natural disaster hazard index, including reading about the Thiessen polygon method, how to map natural disasters in Indonesia, and how to score all-natural disasters in Indonesia. The next stage is data collection, searching for all data related to the mapping process through the official government website. The data collected is data on natural disasters that occurred in Indonesia taken from BNPB in 2007-2019[3] and a map of the surface area of each Regency/City in Indonesia that will be used for the classification of natural disasters [14]. Table 1 below shows some of the collected BNPB data.

Table 1. BNPB DATA

Regency/City	2007	2008	2009	2010	2011	...	2018	2019
Southwest Aceh	1	0	6	0	5	…	9	4
East Aceh	0	2	9	0	1	…	5	0
North Aceh	5	5	17	5	6	…	6	1
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
Yogyakarta	1	0	3	1	2	…	2	1
Kulon Progo	3	4	28	5	3	…	3	3
Sleman	3	0	4	4	8	…	11	6

BNPB data divides natural disasters that occur in Indonesia into three levels of vulnerability [15]. Results The level of vulnerability to natural disasters comes from the value that has been determined by BNPB, which is the total value of natural disasters that occur according to the level of vulnerability divided by the number of natural disasters that occur. The results of the level of vulnerability to natural disasters can be seen in Table 2.

Table 2. RESULTS OF NATURAL DISASTER VULNERABILITY

Disaster Vulnerability	Vulnerability Level
< 3	Low vulnerability
3-7	Moderate vulnerability
> 7	High vulnerability

The next stage is data processing, averaging BNPB data from 2007-2019 for further modeling to produce a map model using the Thiessen polygon method. Thiessen polygon is a

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computational process in determining the average natural disaster in the polygon area. Thiessen polygon shows the points connected to each disaster station using the nearest neighbor search, where each point will be associated with the center point of each disaster station. Optimization of the Thiessen polygon algorithm was carried out to map the classification of natural disasters based on natural disaster data. The flow chart and the Thiessen polygon optimization method can be seen in Figure 3 and Figure 4.

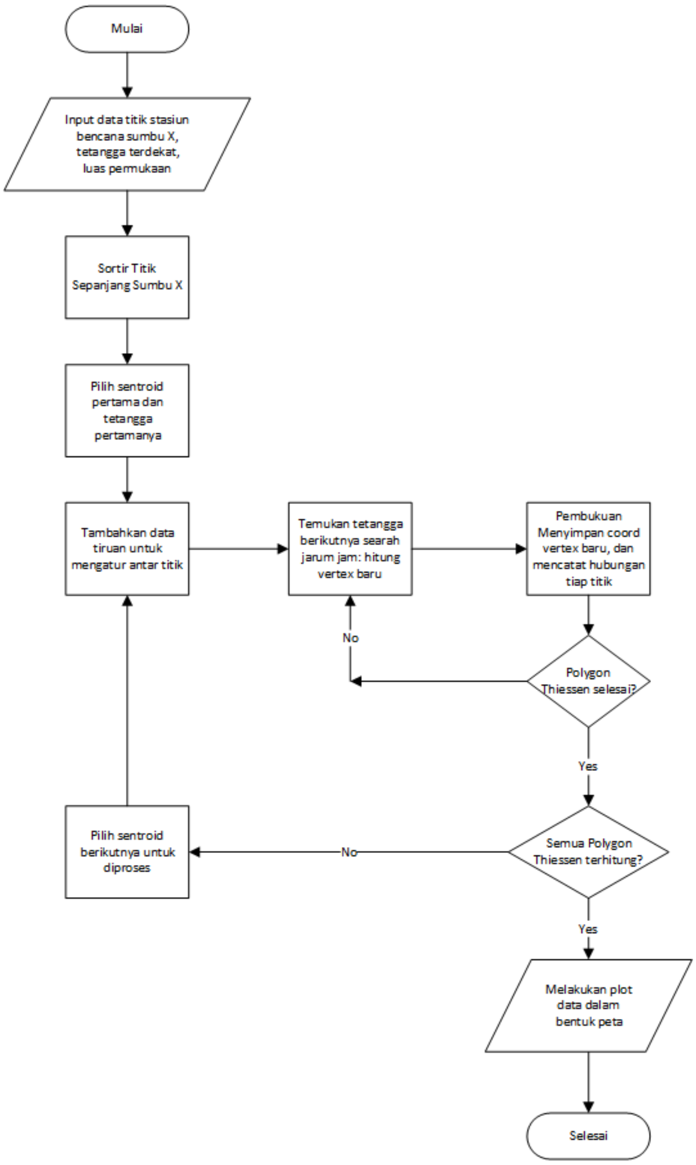

Figure 3. THIESSEN POLYGON METHOD FLOW DIAGRAMS

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Algorima Polygon Thiessen

Input : data[N] ← *data bencana alam perkabupaten sebanyak N*
x ← *titik stasiun bencana alam pada sumbu x*
c ← titik centroid
t ← *titik tetangga terdekat*
A ← *luas permukaan*
cons.thiessen[N] ← *array penampung data bencana alam*
cons.statsion[N] ← *array penampung data stasiun bencana alam*
For $N = x$
If $N = x$ **then**
    Select first *c = t*
    Add *t* ***to*** *dummy point* ***then do***
    Find *next c* ***then*** *set next t*
    cons.station[N] ← A
Else if *polygon thiessen = False* **then**
    Select [x + n]
    Select [c + n] = [t + n]
Else if *add* [t+n] ***to*** *dummy points* **then** ***do***
    Find *next* [c+n] ***then*** *set next* [t+n]
    cons.station[N] ← [A+n]
Else if *polygon thiessen = TRUE* ***then do***

$$thiessen[N] = \left(\frac{cons.station[N]*A+cons.station[N+n]}{A+[A+n]}\right)$$

End if
End For

Figure 4. THIESSEN POLYGON OPTIMIZATION ALGORITHM

The next stage is making a map model, which is entering BNPB data averaged in excel with .csv format like a database for the R program in table format. The analysis consisted of plot analysis from programming and natural disaster-level classification based on the Thiessen polygon method. The plots themselves were separated by region to make it easier to see each area's level of vulnerability and produce a map model of disaster-prone areas in Indonesia [16], [17]. The next stage is to evaluate the results of the study, which is to compare the natural disaster map model that has been made using the Thiessen Polygon method with data that has been collected from BNPB to find out how many errors occur.

III. RESULT AND DISCUSSION

The result of this study is a Map of Natural Disaster Prone Areas in Indonesia in 13 years to display information on areas that are prone to disasters and those that are not. In detail, the discussion is as follows:

A. Disaster Mapping Using Thiessen Polygon Method

Carrying out mapping is for each classification of all the average values for all-natural disasters. It occurs in all regencies/cities in Indonesia.

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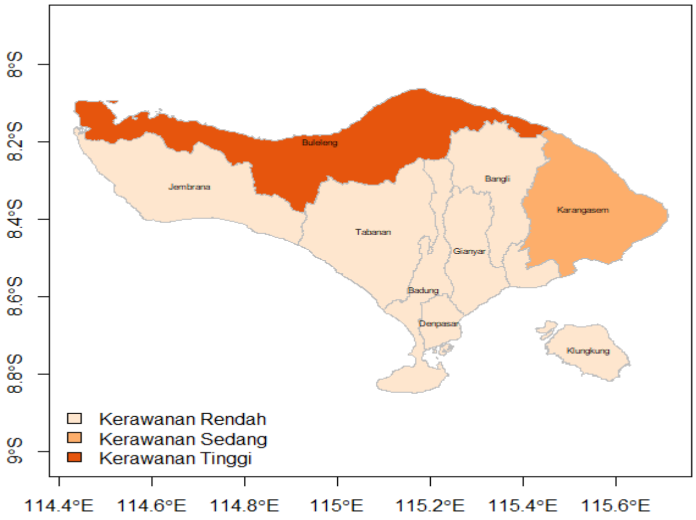

Figure 4. NATURAL DISASTER IN BALI

Figure four shows Regency/City that has a high level of vulnerability is in Buleleng. Regencies/cities with a moderate level of vulnerability are in Karangasem. Regencies/cities with low vulnerability levels are in Jembara, Tabanan, Badung, Denpasar, Gianyar, Bangli, and Klungkung.

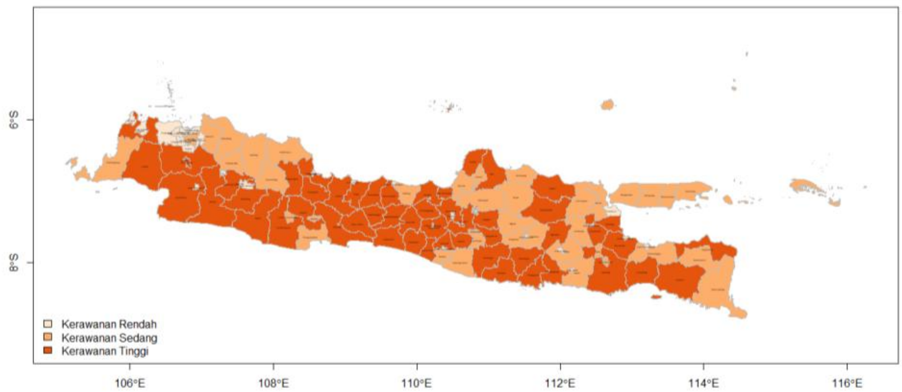

Figure 5. NATURAL DISASTER IN JAVA

Figure 5. Natural Disasters in Java above shows the regencies/cities with a high level of vulnerability are Cianjur, Cirebon, Garut, Bogor City, Kuningan, Majalengka, Lebak, Serang, Bandung, West Bandung, Semarang City, Magelang, Bogor, Ciamis, Boyolali, Brebes, Cilacap, Jepara, Karanganyar, Klaten, Pati, Pekalongan, Kebumen, Kendal, Pemalang, Banjarnegara, Banyumas, Purbalingga, Purworejo, Semarang, Sragen, Tegal, Temanggung, Wonogiri, Sukabumi, Tasikmalaya, Wonosobo, Bojonegoro, Jember, Lumajang, Malang, Mojokerto, Trenggalek, Tuban, Ngajuk, Pacitan, Pasuruan, Ponorogo, Sidoarjo, Situbondo, Tulungagung, Kulon Progo, and Sleman. Regencies/cities with a moderate level of vulnerability are in Bantul, Gunung Kidul, Sumenep, Sampang, Probolinggo, Pamekasan, Ngawi, Magetan, Lamongan,

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Madiun, Kota Malang, Kediri, Jombang, Gresik, Bondowoso, Blitar, Batu, Banyuwangi, Bangkalan, Sukoharjo, Surakarta, Rembang, Kudus, Grobogan, Demak, Blora, Batang, Sumedang, Pangadaran, Purwakarta, Subang, Kota Tasikmalaya, Indramayu, Karawang, Bekasi and Banjar. Regencies/cities with a low level of vulnerability are located in the City of Yogyakarta, Surabaya, the City of Blitar, the City of Madiun, the City of Kediri, the City of Mojokerto, the City of Probolinggo, the City of Pasuruan, Salatiga, the City of Tegal, the City of Magelang, the City of Pekalongan, the City of Sukabumi, the City of Cirebon, the City of Bandung, the City of Bekasi, Depok, and Cimahi.

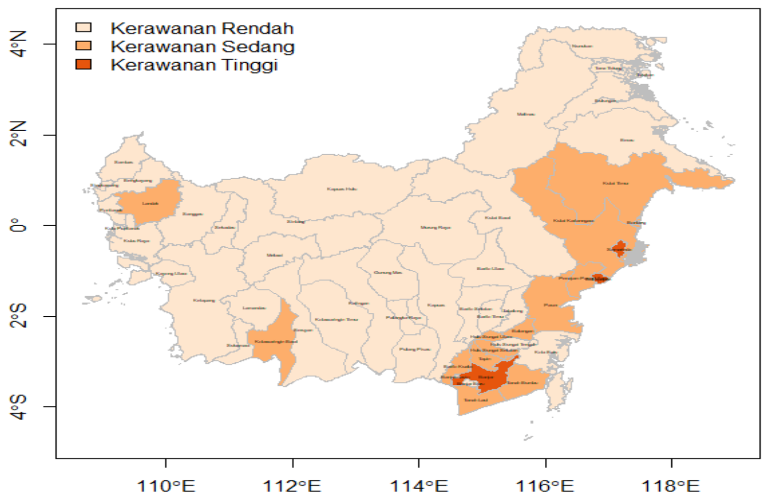

Figure 6. NATURAL DISASTER IN KALIMANTAN

Figure 6. illustrates the Natural Disaster in Kalimantan. Regencies/cities with a high level of vulnerability are located in Banjar, Balikpapan, and Samarinda. Regencies/cities with moderate vulnerability are located in Landak, Bontang, Balangan, Barito Kuala, South Hulu Sungai, North Hulu Sungai, Tanah Bumbu, Tanah Laut, Tapin, West Katowarigin, Kutai Kertanegara, East Kutai, Paser, and North Penajam Paser. Regencies/Cities with a low level of vulnerability are in Tarakan, Nunukan, Malinau, Bulungan, Tana Tidung, Kutai Barat, Berau, East Kotawarigin, Lamandau, Murung Raya, Palangka Raya, Pulang Pisau, Seruyan, Sukamara, Katingan, Kapuas, Gunung Mas, North Barito, East Barit, South Barito, Tabalong, Baru City, Center Hulu Sungai, Banjar Baru, Banjarmasin, Sintang, Singkawang, Sekadau, Sanggau, Sambas, Pontanak, Melawi, Kubu Raya, Pontianak City, Ketapang, Kayong Utara, Kapuas Hulu, dan Bengkayang.

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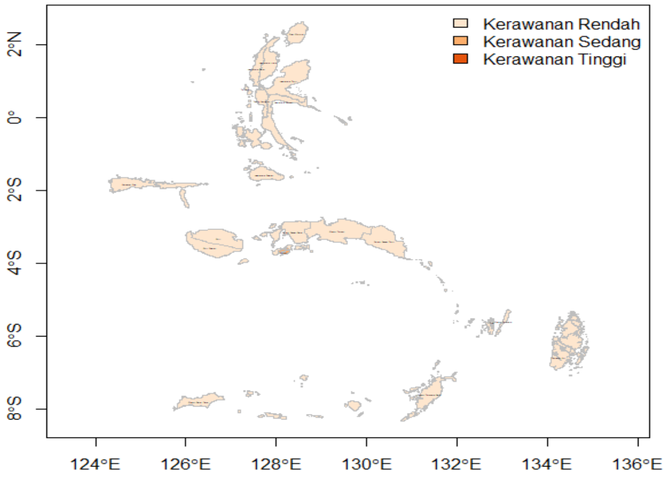

Figure 7. NATURAL DISASTER IN MALUKU

The illustration of natural disasters in Maluku in Figure 7 depicts that the regency/city with a moderate level of vulnerability is in Ambon. The other regencies/cities have a low level of vulnerability.

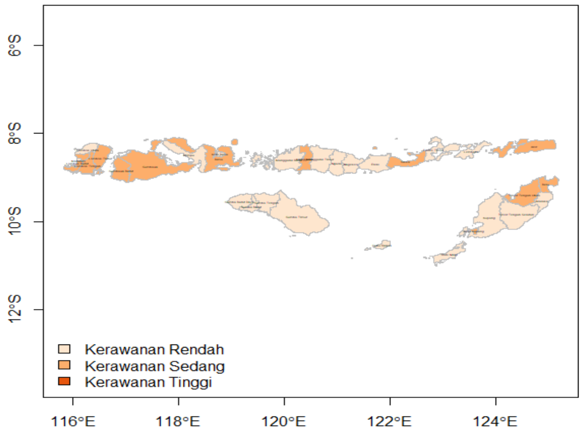

Figure 8. NATURAL DISASTER IN NUSA TENGGARA

The figure above shows that regencies/cities in Nusa Tenggara with moderate levels of vulnerability are in Bima, West Lombok, Sumbawa, Central Lombok, West Sumbawa, East Lombok, Alor, Kota Kupang, Belu, Manggarai, North Central Timor dan Sikka. Other regencies/cities have a low level of vulnerability.

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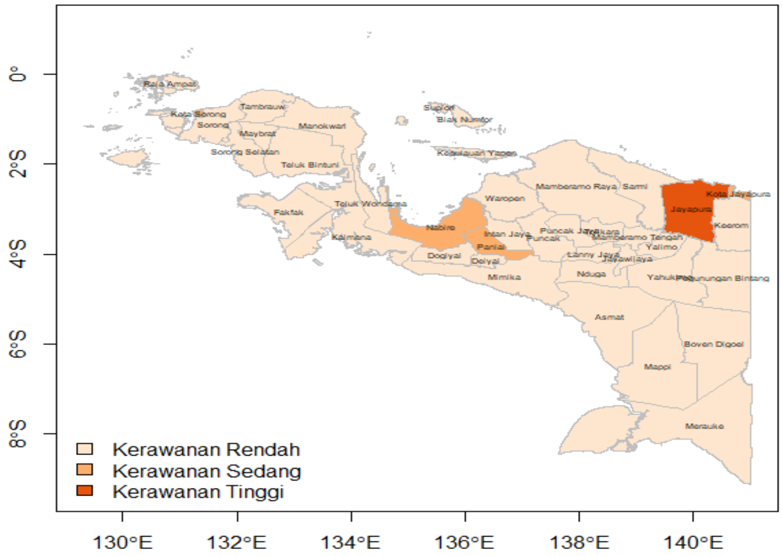

Figure 9. NATURAL DISASTERS IN PAPUA

The figure of Natural Disasters in Papua above explains that the regency/city with a high level of vulnerability is in Jayapura. Regencies/cities with a moderate level of vulnerability are Nabire, Jayapura City, Sorong City, and Paniai. Other regencies/cities have a low level of vulnerability.

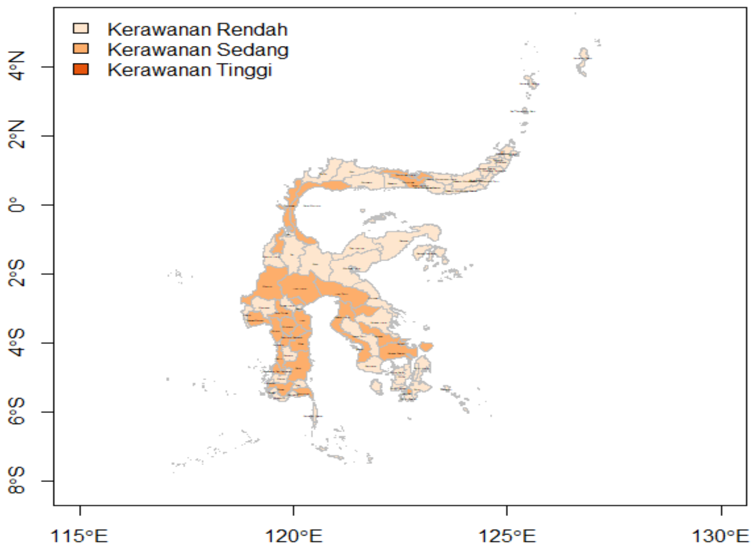

Figure 10. NATURAL DISASTERS IN SULAWESI

The picture above shows that the regencies/cities in Sulawesi with the level of vulnerability to natural disasters are in Wajo, Sidenreng Rappang, Tana Toraja, Pariggi Muotong, Pinrang, Pangkajene and Islands, Polewali Mandar, Mamuju, Manado, Luwu, Kolaka, East Luwu, Kolaka Utara, North Luwu, Konawe, Kendari, Bone, Barru, Bau-Bau, Bulukumba South Konawe, Donggala, Gowa dan Enrekang. Other regencies/cities have a low level of vulnerability.

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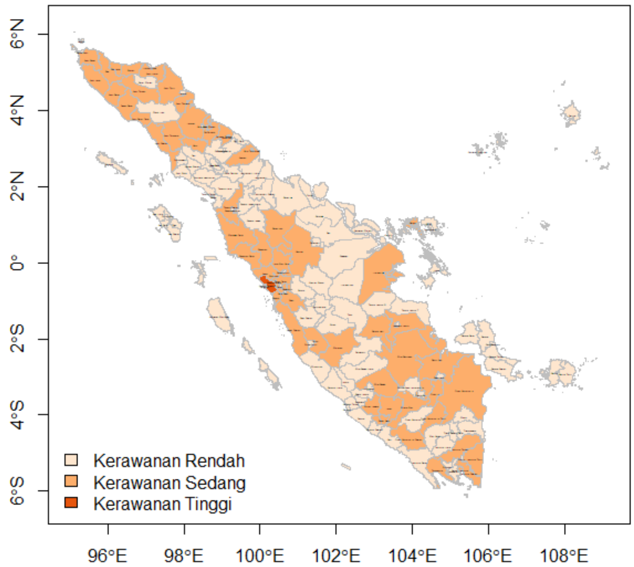

Figure 11. NATURAL DISASTER IN SUMATERA

The figure above shows the level of vulnerability to natural disasters in Sumatra. Padang Pariaman is a regency with a high level of vulnerability. Besides, Banyu Asin, East Lampung, West Aceh, Central Lampung, Bireuen, Solok, Batam, Tanah Datar, Tanggamus, Musi Banyuasin, Sawahlunto, Southwest Aceh, Bandar Lampung, Pesisir Selatan, Aceh Tamiang, Padang, South Lampung, Deli Serdang, Musi Rawas, Aceh Besar, Lima Puluh Kota, Aceh Jaya, Karo, Agam, Ogan Ilir, South Aceh, Asahan, Kampar, Serdang Bedagai, Central Aceh, Ogan Komering Ilir, Southeast Aceh, Indragiri Hilir, East Aceh, South Ogan Komering Ulu, South Tapanuli, West Pasaman, North Aceh, Bireuen, Mandailing Natal, Nagan Raya, Pidie, East Ogan Komering Ulu, Langkat, Pidie Jaya, Pagar Alam, The city of Medan, and Pasaman have moderate vulnerability. Moreover, other regencies/cities have a low level of vulnerability.

B. Evaluation of Research Results

The map made was compared with data that has been taken from BNPB to find out how much difference there is between BNPB data and data using the Thiessen polygon method. The parameters used include the level of vulnerability with a low vulnerability range of less than 3, moderate vulnerability from 3-7, and high vulnerability more than 7. Table 3 illustrates the results of the comparison.

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Table 3. COMPARISON RESULT

Regency/ city	Level of Vulnerability Using BNPB Data	Vulnerability Using Thiessen Polygon
Southwest Aceh	Moderate	Moderate
East Aceh	Moderate	Moderate
North Aceh	Moderate	Moderate
Banda Aceh	Low	Low
Bener Meriah	Low	Low
⋮	⋮	⋮
Jayapura City	Low	Moderate
Nabire	Low	Moderate
Paniai	Low	Moderate
Sorong City	Low	Moderate
Jayapura	Low	high

The comparison result from Table 3 above illustrates data from BNPB showing that from 508 regencies/cities in Indonesia, 302 of them have a low level of vulnerability, 148 regencies/cities have a moderate level of vulnerability, and 58 regencies/cities have a high level of vulnerability. Furthermore, data from the Polygon Thiessen method shows that out of 508 regencies/cities in Indonesia, there are 297 regencies/cities with a low level of vulnerability, 152 regencies/cities have a moderate, and 59 regencies/cities have a high level of vulnerability. As for the difference in data in the Papua region, BNPB data shows that the Papua region has a low level of vulnerability. While the Thiessen polygon method, the Papua region of Nabire regencies/city, Sorong City, Paniai, and Jayapura City have a moderate level of vulnerability, and Jayapura has a high level of vulnerability. The average data in the Papua region does not meet the indicators of medium and high levels of vulnerability. Therefore, one average data was included in the moderate level of vulnerability, and two are included in the high level.

IV. CONCLUSION

To sum up, the Thiessen Polygon method can divide disasters in Indonesia into three levels of vulnerability. Comparison of BNPB data and Polygon Thiessen data shows that BNPB has a low vulnerability level of 302, a moderate vulnerability level of 148, and a high level of vulnerability of 58. Besides, the Thiessen polygon has a low vulnerability level of 297, a moderate vulnerability of 158, and a high vulnerability of 59. Results Comparison of BNPB data and the Polygon Thiessen method found five differences from 40 data in the Papua region. The Thiessen polygon method can create thematic maps for natural disasters, provided that the data must meet

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each of the indicators made. Otherwise, there will be errors like in the Papua region. This research can potentially contribute as a reference for the regencies/cities governments dealing with natural disasters in Indonesia, such as BNPB or other organizations related to the use of data or maps of natural disasters. Suggestions for further research are to create an application-based information system to be accessed in real-time.

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