Spatial Mapping of Diphtheria Vulnerability Level in East Java, Indonesia, using Analytical Hierarchy Process – Natural Break Classification

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Abstract. Diphtheria is a serious infectious disease induced by the Corynebacterium Diphtheriae bacteria and often causes outbreaks (extraordinary events) in various regions. Based on data from the Ministry of Health, East Java is the biggest benefactor to diphtheria cases in Indonesia. Diphtheria cases in East Java tend to increase, especially in 2018 there were 753 diphtheria cases in 38 districts. Efforts made to prevent, treat, and control diphtheria outbreaks by the government are to analyze the level of susceptibility to diphtheria. This paper proposes a new approach to analyze the level of diphtheria susceptibility using the analytical hierarchy process (AHP) and natural breaks classification in East Java Province, Indonesia. AHP method is used to obtain diphtheria susceptibility values based on seven criteria, such as the number of sufferers, number of deaths, DPT 1, DPT 2, DPT 3 immunization, population density, and humidity. Natural break classification is used to classify the vulnerability values from AHP into three levels of vulnerability, consisting of low, medium, and high. The results of the grouping are displayed in the form of spatial mapping in the form of a web-based geographic information system (web-GIS) on the determination of the diphtheria vulnerability level using the AHP-natural breaks classification. The GVF evaluation for 2016, 2017, and 2018 are respectively 0.66, 0.67, and 0.65 (more than 0.5), which means that the proposed method achieved accurate and significant classification. Spatial-temporal analysis for 2013-2018 also achieves accurate and significant with a GVF value of 0.77. The spatial-temporal analysis can predict the high potential for vulnerability.

1. Introduction
Diphtheria is a serious infectious disease which attacks the upper respiratory system [1]. It is induced by the Corynebacterium Diphtheriae bacteria. Diphtheria is often characterized by the growth of a gray membrane that covers the tonsils and part of the respiratory tract, making it difficult to breathe. Diphtheria is a health problem since thousands of years ago that have attacked human health which can lead to complications and death. Indonesia is a country with a high rate of diphtheria cases in the world and contributes 1,026 cases in 2018 which is ranked 4th in the world after India, Yemen, and Nigeria [2].

Diphtheria is a case of "recurring disease" in East Java Province, which ranks highest in Indonesia [3][4]. From year to year in East Java Province, the number of Diphtheria sufferers is reported to continue increasing. Diphtheria cases in East Java reached its attained in 2012, as many as 955 cases with 37 deaths due to and have spread in 38 districts and cities. Based on data from the Ministry of Health, Diphtheria cases in East Java are the biggest benefactor to cases in Indonesia (74%) and even in
the world [5]. Diphtheria cases in East Java tend to increase, especially in 2018 there were 753 diphtheria cases from around 39 million people in 38 districts and cities.

Efforts to reduce diphtheria cases are basic immunization for infants with Diphtheria-Pertussis-Tetanus and Hepatitis B (DPT-HB-Hib) vaccines [6]. Immunization is one of the health interventions that has proven to be the most cost-effective (cheap) because it can prevent and reduce the incidence of morbidity, disability, and death due to DPT-HB-Hib which is estimated to be 2 to 3 million deaths each year. The immunization program will be effective or can have an impact on diphtheria reduction by diphtheria immunization if the immunization coverage is reached 95% evenly in all villages. DPT immunization is the most dominant factor in preventing diphtheria risk [3] [4], however, other factors cause diphtheria disease to continue and spread. Several studies have analyzed and tested the factors that cause diphtheria outbreaks, including demographic factors [3] [4] [7], environment [3] [4], and nutrition [8].

An assessment of the level of susceptibility to diphtheria needs to be carried out for the prevention and control of diphtheria by the government. The Indonesian National Disaster Management Agency guides the assessment of disaster risks including diseases consisting of hazard factors, vulnerability, and the capacity of the community, NGOs, and the government [9]. The vulnerability level index is divided into three levels, consisting of low, medium, and high risk.

Diphtheria vulnerability analysis involves several different criteria so it is necessary to design a multiple criteria decision analysis (MCDA), model. The analytical hierarchy model (AHP) [10] is a widely used method for analyzing complex discrete alternative decision problems with multiple qualitative criteria.

This paper proposes a new approach to analyze the level of diphtheria susceptibility using AHP and natural breaks classification in East Java Province, Indonesia. AHP method is used to obtain diphtheria susceptibility values based on seven criteria, which consist of the number of sufferers, number of deaths, DPT 1, DPT 2, DPT 3 immunization, population density, and humidity. Natural break classification is used to classify the vulnerability values from AHP into three levels of vulnerability, consisting of low, medium, and high. The results of the grouping are displayed in the form of spatial mapping in the form of a web-based geographic information system (web-GIS). The analysis of diphtheria vulnerability can prevent, treat, and control diphtheria outbreaks by the government.

2. Literature Review
Izza and Soenarnatalina [3] conducted a statistical analysis of diphtheria using spatial data associated with risk factors in 38 districts and cities of East Java Province in 2010 and 2011. The geographic information system-based spatial analysis was carried out by overlaying diphtheria variables with variable factors. risks consisting of population density, female population dominance, low education level, healthy housing coverage, expenditure levels per capita, DPT3 immunization, and DT immunization. The National Disaster Management Agency of Indonesia provides guidelines for disaster risk assessment including disease which consists of hazard, vulnerability, and capacity factors for communities, NGOs, and government [9]. The vulnerability level index is divided into three levels, consisting of low, medium, and high risks.

Several studies conducted a multi-criteria risk analysis on several disease outbreaks. Ali and Ahmad [11] mapped the dengue risk areas in the Kolkata Municipal Corporation based on environmental parameters using AHP as a spatial decision support system. Bhatt and Joshi [12] integrated Geospatial and Multi-Criteria Evaluation (AHP) to determine the risk zone for malaria in the Vadodara district, Gujarat, based on physical environmental and climatic factors, then divided it into three, namely, high, medium, and low risk zones. Jahanifard et al. [13] analyzed the risk level of cutaneous leishmaniasis in Khuzestan Province, Iran, using integrative GIS, RS, and AHP methods based on thirteen influential criteria. Disease risk assessment provides valuable information that can guide policymakers and health authorities in making the right decisions before a possible disease outbreak occurs.

This paper presents a methodology for assessing the level of diphtheria risk based on MCDA, which consists of the number of sufferers, the number of deaths, DPT 1, DPT 2, DPT 3 immunization, population density, and humidity using AHP and natural break classification. The diphtheria vulnerability level is divided into three levels as per the guidelines of The National Disaster Management
Agency of Indonesia, consisting of low, medium, and high. Spatial visualization using web-based geographic information systems can clearly show the spread of diphtheria in 38 districts and cities in East Java Province.

3. Methodology
The methodology for generating spatial mapping from the diphtheria vulnerability level in East Java, Indonesia, using the analytical hierarchy process and natural breaks classification (AHP-Natural Breaks) can be seen in Figure 1.

![Figure 1. The methodology of diphtheria spatial vulnerability mapping.](image)

According to Figure 1, the methodology for displaying the diphtheria vulnerability mapping built on a web-based geographic information system generally consists of collecting input data, determining the vulnerability level, and displaying the output in the form of spatial vulnerability mapping for all districts in East Java. A detailed explanation of the system diagram in Figure 1 is as follows:

1. Data Collection
   The data collection used for input was obtained through a survey of the East Java Health Service. The data used in this study included the number of sufferers, number of deaths, DPT 1, DPT 2, DPT
   Database
   The database stores all spatial data (East Java base map) and related attributes based in PostgreSQL for further processing.

2. Analytical Hierarchy Process (AHP) and Natural Breaks Classification Process
   AHP calculates the diphtheria vulnerability value based on the importance level of the influencing factors. Meanwhile, the natural breaks classification is used to classify the diphtheria vulnerability value from AHP into low, medium, and high vulnerability levels.

3. Spatial Mapping Visualization
   The results of determining the level of diphtheria vulnerability are displayed in a web-based map by querying the database. This stage visualized the level of vulnerability in all districts in East Java with different colors.

3.1 Study Area
East Java Province is geographically located between 111°0' East Longitude - 114°4' East Longitude and 7° 12' South Latitude - 8°48" South Latitude, with an area of 47,963 km² covering two main parts. Namely mainland East Java and the Madura Islands [14]. The land area of East Java is 88.70 percent or
42,541 km$^2$, while the Madura Islands have an area of 11.30 percent or 5,422 km$^2$. The total population in 2010 reached 37,476,757 people. East Java is administratively divided into 29 districts and 9 cities, with the City of Surabaya as the provincial capital. This makes East Java a province that has the largest number of districts and cities in Indonesia. The multi-polygon base map of East Java province used in this study can be seen in Figure 2.

3.2 Analytical Hierarchy Process (AHP) for Vulnerability Value

Analytical Hierarchy Process (AHP) is used to solve complex multi-criteria problems into a hierarchy [10]. A hierarchy describes a complex problem in a more structured and systematic. AHP is a decision support method by performing pairwise comparisons between the choice criteria and also pairwise comparisons between the available options. The value of diphtheria vulnerability is determined based on 7 criteria, consisting of the number of sufferers, number of deaths, DPT 1, DPT 2, DPT 3 immunization, population density, and humidity. The criteria that affect the level of diphtheria susceptibility are determined based on the calculation of the correlation of the data between these factors, discussions with doctors as experts, and the East Java health office as stakeholders. In general, 3 factors influence, they are the number of diphtheria cases, DPT immunization, and population density. These three factors are further decomposed into a hierarchy tree as shown in Figure 3.

![Figure 3. AHP hierarchy tree for diphtheria vulnerability.](image)
are given a value of 1. The intensity of importance and meaning introduced by Saaty [10] can be seen in Table 1.

**Table 1. The intensity of importance in AHP**

| Intensity of Importance | Meaning                                      |
|-------------------------|----------------------------------------------|
| 1                       | The two elements are equally important.       |
| 3                       | One element is slightly more important than the other. |
| 5                       | One element is more important than the other. |
| 7                       | One element is absolutely more essential than any other. |
| 9                       | One element is absolutely more important than any other. |
| 2, 4, 6, 8              | The values between two values of adjacent considerations. |

The weighting of a criterion requires an intensity value of importance for each criterion. In the AHP process to determine the diphtheria susceptibility value, a priority approach is carried out based on the intensity value as shown in Table 1. The criteria with the highest priority are given an intensity value of 9 and the criteria with the lowest priority are given an intensity value 1. In this study, the highest priority is the number of sufferers given a value. intensity 8. The intensity value for each criterion is the number of sufferers = 9, number of deaths = 7, DPT 1 = 5, DPT 2 = 3, DPT 3 = 3, population density = 3, and humidity = 1. The criteria weighting matrix based on the priority value can be seen in Table 2.

**Table 2. Criteria weighting matrix.**

| Criteria            | Number of Sufferers | Number of Deaths | DPT 1 | DPT 2 | DPT 3 | Population Density | Humidity |
|---------------------|---------------------|------------------|-------|-------|-------|-------------------|----------|
| Number of Sufferers | 1                   | 9/7              | 9/5   | 9/3   | 9/3   | 9/3               | 9        |
| Number of Deaths    | 7/9                 | 1                | 7/5   | 7/3   | 7/3   | 7/3               | 7/1      |
| DPT 1               | 5/9                 |                  | 1     | 1     | 1     | 1                 | 3        |
| DPT 2               | 3/9                 | 3/7              | 3/5   | 1     | 1     | 1                 | 3        |
| DPT 3               | 3/9                 | 3/7              | 3/5   | 1     | 1     | 1                 | 3        |
| Population Density  | 3/9                 | 3/7              | 3/5   | 3/5   | 3/5   | 1                 | 3        |
| Humidity            | 1/9                 | 1/7              | 1/5   | 1/3   | 1/3   | 1                 | 1        |

Data for each district for each criterion must have equal value. This is necessary to get the order of global priority values. In determining the value of diphtheria susceptibility, the values for immunization criteria were reversed, which consisted of DPT 1, DPT 2, and DPT 3. The smaller the value, the higher the level of vulnerability. Meanwhile, the remaining criteria, if the value is higher, will result in a higher level of vulnerability. The next step to take is the normalization of alternative local priority values to obtain global priority values which are the values of diphtheria vulnerability.

### 3.3 Natural Breaks Classification

The AHP process produces a global priority value which is a diphtheria susceptibility value. To classify the vulnerability values into low, medium, and high levels of vulnerability, a classification method is needed. Jenks's natural break is a method that finds the best ranges by minimizing variation as closely as possible [15]. The stages for getting the best group with natural breaks are as follows:

1. Compute the mean of the group data
2. Calculate the squared deviation between classes (SDCM) with equation
6

\[ SDCM = \sum_{i=1}^{n} \sum_{i=1}^{n} (x_i - Z_{o_i})^2 \]  

where \( Z_{o_i} \) is a standard deviation value, \( n \) is total data and \( x_i \) is the data value.

3. Calculate the sum of the squares of the deviations from the mean (SDAM) with

\[ SDAM = \sum_{i=1}^{n} (x_i - \bar{x})^2 \]  

where \( \bar{x} \) is a mean, \( n \) is total data and \( x_i \) is the data value.

4. Reduce SDCM from SDAM (SDAM-SDCM). This is the same as the sum of the squared deviations from the classroom facilities (SDCM).

5. After examining each SDCM, a decision is made to move one unit from the class with the largest SDCM to the class with the lowest SDCM.

The natural breaks classification method is tested based on the Goodness of Variance Fit (GVF). If the value is close to 1, it means that the classification results are very accurate. The GVF equation is as follows:

\[ GVF = 1 - \frac{\sum_{i=1}^{n} \sum_{i=1}^{n} (x_i - x_i')^2}{\sum_{i=1}^{n} (x_i - \bar{x})^2} \]  

Or it can be defined as GVF as the result of (SDAM - SDCM) / SDAM. GVF ranges from 0 (worst) to 1 (very perfect).

4. Result and Discussion

This section analyzes the results of the calculation and determination of the diphtheria vulnerability level using AHP-Natural breaks classification and the results of web-GIS-based spatial mapping.

4.1 Diphtheria Vulnerability Level and Spatial Mapping Each Year

An experiment with the AHP-Natural breaks classification was conducted to determine the level of diphtheria vulnerability in 38 districts in East Java. The data used are based on 7 factors that affect the level of diphtheria vulnerability, consisting of the number of sufferers, the number of deaths, DPT 1, DPT 2, DPT 3, population density, and humidity in the 2016-2018 period. The AHP weighting matrix uses the intensity of importance value as in Table 2. The result of the AHP process is the level of vulnerability value. The level of vulnerability value is classified into three classes, consisting of the low, medium, and high using natural breaks classification. The value of diphtheria vulnerability and classification results can be seen in Table 3.

Spatial mapping of the diphtheria vulnerability level can provide an overview of the spread of vulnerability levels in 38 districts in East Java Province based on web-GIS. The depiction is done by giving different colors that indicate the level of vulnerability in each district. The red color indicates the high diphtheria vulnerability level, yellow for the medium level of vulnerability, and green for the low level of vulnerability. Spatial mapping and the number of district graph classification results from AHP-Natural breaks in 2016-2018 can be seen in Figure 4.

Based on Table 3 and Figure 4, in 2016 there are 2 districts with a high level of diphtheria vulnerability, consisting of Malang (City) and Blitar. In 2017 there are 5 high-level districts, consisting of Pasuruan, Surabaya (City), Probolinggo, Sampang, and Sidoarjo. In 2018, there are 4 high-level districts, consisting of Ponorogo, Trenggalek, Surabaya (City), and Malang. The results of the classification method test are calculated by calculating the Goodness of Variance Fit (GVF) with equation (3). The higher the GVF, the better the classification results. The GVF value of the AHP-Natural breaks classification for each 2016-2018 can be seen in Table 4. The GVF values for 2016, 2017, and 2018 are respectively 0.66, 0.67, and 0.65 (more than 0.5), it can be concluded that the AHP -Natural breaks achieved accurate and significant classification.
4.2 Spatial-Temporal Diphtheria Vulnerability Level

Spatial temporal analysis according to the cumulative diphtheria vulnerability level in several years can be used to predict districts that have the potential to have a high level of vulnerability. Table 3 is the calculation result of AHP-Natural breaks classification cumulatively for 2013-2018 (6 years) based on 7 factors that affect the level of diphtheria vulnerability, consisting of the number of sufferers, number of deaths, DPT 1, DPT 2, DPT 3, population density, and humidity in 38 districts in East Java. The AHP weighting matrix uses the intensity of importance value as in Table 2.

Table 3. The diphtheria vulnerability value and classification results with the AHP-Natural breaks classification in 2016-2018

| District       | 2016  | 2017  | 2018  |
|----------------|-------|-------|-------|
|                | AHP Value | Natural Break Classification | AHP Value | Natural Break Classification | AHP Value | Natural Break Classification |
| Pacitan        | 0.0011 | Low   | 0.0008 | Low   | 0.0010 | Low   |
| Ponorogo       | 0.0013 | Low   | 0.0015 | Low   | 0.0091 | High  |
| Trenggalek     | 0.0017 | Low   | 0.0013 | Low   | 0.0089 | High  |
| Tulungagung     | 0.0028 | Low   | 0.0020 | Low   | 0.0024 | Low   |
| Lumajang       | 0.0017 | Low   | 0.0022 | Low   | 0.0041 | Medium |
| Bondowoso      | 0.0011 | Low   | 0.0013 | Low   | 0.0012 | Low   |
| Pasuruan       | 0.0037 | Medium | 0.0118 | High  | 0.0035 | Medium |
| Jombang        | 0.0027 | Low   | 0.0028 | Medium | 0.0034 | Medium |
| Nganjuk        | 0.0027 | Low   | 0.0034 | Medium | 0.0023 | Low   |
| Madiun         | 0.0012 | Low   | 0.0011 | Low   | 0.0016 | Low   |
| Magetan        | 0.0010 | Low   | 0.0013 | Low   | 0.0013 | Low   |
| Ngawi          | 0.0018 | Low   | 0.0019 | Low   | 0.0020 | Low   |
| Bojonegoro     | 0.0020 | Low   | 0.0030 | Medium | 0.0022 | Low   |
| Tuban          | 0.0021 | Low   | 0.0042 | Medium | 0.0027 | Medium |
| Lamongan       | 0.0017 | Low   | 0.0021 | Low   | 0.0023 | Low   |
| Bangkalan      | 0.0023 | Low   | 0.0019 | Low   | 0.0025 | Low   |
| Pamekasan      | 0.0013 | Low   | 0.0016 | Low   | 0.002 | Low   |
| Kediri (City)  | 0.0007 | Low   | 0.0009 | Low   | 0.0009 | Low   |
| Blitar (City)  | 0.0020 | Low   | 0.0008 | Low   | 0.0006 | Low   |
| Malang (City)  | 0.0107 | High  | 0.0026 | Medium | 0.0022 | Low   |
| Probolinggo (City) | 0.0005 | Low   | 0.0008 | Low   | 0.0007 | Low   |
| Pasuruan (City) | 0.0007 | Low   | 0.0027 | Medium | 0.0010 | Low   |
| Mojokerto (City) | 0.0009 | Low   | 0.0008 | Low   | 0.0012 | Low   |
| Madiun (City)  | 0.0011 | Low   | 0.0006 | Low   | 0.0009 | Low   |
| Surabaya (City) | 0.0068 | Medium | 0.0092 | High  | 0.0075 | High  |
| Batu (City)    | 0.0007 | Low   | 0.0015 | Low   | 0.0007 | Low   |
| Blitar         | 0.0133 | High  | 0.0026 | Medium | 0.0029 | Medium |
| Kediri         | 0.0027 | Low   | 0.003 | Medium | 0.0036 | Medium |
| Mojokerto      | 0.0024 | Low   | 0.0025 | Medium | 0.0039 | Medium |
| Banyuwangi     | 0.0025 | Low   | 0.0028 | Medium | 0.0027 | Medium |
| Gresik         | 0.0055 | Medium | 0.0041 | Medium | 0.0031 | Medium |
| Jember         | 0.0040 | Medium | 0.0037 | Medium | 0.0044 | Medium |
| Malang         | 0.0044 | Medium | 0.0054 | Medium | 0.0129 | High  |
| Probolinggo    | 0.0054 | Medium | 0.0071 | High  | 0.0021 | Low   |
| Sampang        | 0.0054 | Medium | 0.0069 | High  | 0.0019 | Low   |
| Sidoarjo       | 0.0057 | Medium | 0.0066 | High  | 0.0043 | Medium |
| Situbondo      | 0.0015 | Low   | 0.0028 | Medium | 0.0022 | Low   |
| Sumenep        | 0.0054 | Medium | 0.0022 | Low   | 0.0020 | Low   |
Figure 4. Spatial mapping and number of district graph classification results from AHP-Natural breaks (a) 2016; (b) 2017; (c) 2018.

Table 4. GVF value of AHP-Natural breaks classification in 2016-2018

| Year | GVF |
|------|-----|
| 2016 | 0.66 |
| 2017 | 0.67 |
| 2018 | 0.65 |

Spatial-temporal mapping of the diphtheria vulnerability level and the graph that shows the number of district classification according to cumulative AHP-Natural breaks calculation in 2013-2018 can be seen in Figure 5. Based on Table 5 and Figure 5, Surabaya (City) district has a high diphtheria vulnerability level and 11 districts with medium level status. This means that the Surabaya (City) district has a high potential for vulnerability compared to other districts. In spatial-temporal testing with AHP-Natural breaks classification, the value of GVF = 0.77 is obtained so that the classification achieves accurate and significant results (more than 0.5).
Table 5. The cumulative diphtheria vulnerability value and classification results with the AHP-Natural breaks classification in 2013-2018

| District                | Cumulative 2013-2018 AHP Value | Natural Break Classification | District                | Cumulative 2013-2018 AHP Value | Natural Break Classification |
|------------------------|--------------------------------|------------------------------|------------------------|--------------------------------|------------------------------|
| Pacitan                | 0.0010                         | Low                          | Malang (City)          | 0.0041                         | Medium                       |
| Ponorogo               | 0.0027                         | Low                          | Probolinggo (City)     | 0.0006                         | Low                          |
| Trenggalek             | 0.0028                         | Low                          | Pasuruan (City)        | 0.0010                         | Low                          |
| Tulungagung            | 0.0033                         | Low                          | Mojokerto (City)       | 0.0012                         | Low                          |
| Lumajang               | 0.0023                         | Low                          | Madiun (City)          | 0.0009                         | Low                          |
| Bondowoso              | 0.0018                         | Low                          | Surabaya (City)        | 0.0080                         | High                         |
| Pasuruan               | 0.0057                         | Medium                       | Batu (City)            | 0.0009                         | Low                          |
| Jombang                | 0.0028                         | Low                          | Blitar                 | 0.0050                         | Medium                       |
| Nganjuk                | 0.0041                         | Medium                       | Kediri                 | 0.0032                         | Low                          |
| Madiun                 | 0.0013                         | Low                          | Mojokerto              | 0.0029                         | Low                          |
| Magetan                | 0.0013                         | Low                          | Banyuwangi             | 0.0029                         | Low                          |
| Ngawi                  | 0.0018                         | Low                          | Gresik                 | 0.0038                         | Medium                       |
| BOjonegoro             | 0.0027                         | Low                          | Jember                 | 0.0064                         | Medium                       |
| Tuban                  | 0.0025                         | Low                          | Malang                 | 0.0065                         | Medium                       |
| Lamongan               | 0.0002                         | Low                          | Probolinggo            | 0.0039                         | Medium                       |
| Bangkalan              | 0.0062                         | Medium                       | Sampang                | 0.0041                         | Medium                       |
| Pamekasan              | 0.0016                         | Low                          | Sidoarjo               | 0.0061                         | Medium                       |
| Kediri (City)          | 0.0008                         | Low                          | Situbondjo             | 0.0022                         | Low                          |
| Blitar (City)          | 0.0011                         | Low                          | Sumenep                | 0.0027                         | Low                          |

Figure 5. Spatial-temporal mapping and number of district graph classification result from cumulative AHP-Natural breaks classification in 2013-2018.

This system for assessing the level of diphtheria vulnerability with AHP-Natural breaks classification and spatial mapping can be used as a basis for prevention and control of diphtheria, so as to minimize risks in each district in East Java. This system can also be used as a decision support system on the effectiveness of giving DPT immunization throughout East Java and improving health facilities for diphtheria sufferers.

5. Conclusion

The GVF evaluation results on the determination of the diphtheria vulnerability level using the AHP-Natural breaks classification based on 7 criteria consisting of the number of sufferers, number of deaths, DPT 1, DPT 2, DPT 3, population density, and humidity for 2016, 2017 and 2018 are respectively 0.66, 0.67, and 0.65 (more than 0.5), so it achieved accurate and significant classification. Spatial-temporal analysis based on the cumulative calculation of AHP-Natural breaks classification for 2013-2018 also achieves accurate and significant with a GVF value of 0.77. The spatial-temporal analysis can predict the high potential for vulnerability. This system for assessing the level of diphtheria vulnerability with
AHP-Natural breaks classification and spatial mapping can be used as a decision support system for the prevention and control of diphtheria. Future work, the development of a classification method is needed to get more accurate results. Besides, it is necessary to add other criteria that affect the diphtheria vulnerability level.

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