Jurnal Ilmiah Matematika dan Terapan
Volume 21 Number 2 December 2024 (Pages 100 - 107)
doi: https://doi.org/10.22487/2540766X.2024.v21.i2.17401

JIMT
Jurnal Ilmiah Matematika dan Terapan

ISSN : 2540 – 766X

BIPLOT ANALYSIS FOR SPATIAL MAPPING OF DENGUE HEMORRHAGIC FEVER (DHF) INCIDENCE IN INDONESIA

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ABSTRACT

Dengue fever (DHF) is a serious threat to Indonesian public health, with the dengue virus spread by the Aedes aegypti mosquito continuing to claim victims in all provinces in Indonesia. The drastic variation of DHF incidence between provinces requires an in-depth understanding of its distribution pattern. Biplot analysis allows researchers to identify patterns based on factors that influence the incidence of DHF in different provinces. This study aims to identify the spatial distribution pattern of DHF in Indonesia using biplot analysis, an approach that allows complex visualization of factors affecting DHF incidence. Results showed that 62.48% of the data variation could be explained through biplot representation, revealing spatial distribution patterns, proximity between objects and diversity between variables. Key findings include the identification of provinces with the highest DHF cases (56,388 cases) in quadrant IV, the high incidence of DHF cases was associated with similar characteristics of average air humidity. In addition, there was significant variation in the number of DHF cases between provinces indicating disparities in the number of DHF cases in different parts of Indonesia, as well as relative uniformity in the percentage of households with proper sanitation (descriptive average of 86.62%). The results of this study are expected to assist policy makers in formulating more effective and targeted dengue prevention and control strategies, potentially reducing the incidence of dengue and improving the health of the Indonesian people.

Keywords : Dengue Hemorrhagic Fever (DHF), Biplot Analysis, Public Health

I. INTRODUCTION

Dengue Hemorrhagic Fever (DHF) has become a significant global threat to public health in recent decades (Sugiyatmi, 2023). According to the World Health Organization (WHO) DHF is now endemic in more than 100 countries and every year, an estimated 400 million people are infected with the dengue virus, 100 million people fall ill, and 21,000 deaths are reported (Alghsham, Shariq, & Rasheed, 2023). Dengue fever (DHF) is an acute febrile illness caused by dengue virus (DENV) infection, which is transmitted to humans through arthropod vectors, primarily through the bite of female mosquitoes of the genus Aedes, especially the species Aedes albopictus and Aedes aegypti. DHF is an environment-based disease that often causes Extraordinary Events (KLB) and causes death (Setryawan, 2020).

In 2023 there were 114,720 cases of DHF with 894 deaths, cases and deaths from DHF decreased compared to 2022 which amounted to 143,266 cases and 1,237 deaths (Kemenkes RI, 2023). One of the factors causing the occurrence of DHF disease is due to environmental factors that can increase mosquito breeding is the physical environment of the house, the biological environment, and the larval index (Shofifah, Widyartanto, & Sulistyorini, 2023). A study by Lestari et al (2023) showed that in addition to climatic factors, environmental factors are also risk factors for DHF. The role of the environment is very influential on the presence of vectors that result in the occurrence of DHF disease (Ernyasih et al, 2021).

On the other hand, research by Mahardika et al (2023) highlighted the importance of health services in influencing the risk of DHF. Disease patterns in Indonesia are very different from one region to another. One of the factors that can contribute to the high incidence of dengue fever is high humidity (Ghaisani, Sulistiawati, & Lusida, 2021). This level of humidity is closely related to the presence of Aedes aegypti mosquito larvae (Mujiarto et al., 2024).

To understand and map the factors influencing the incidence of DHF in Indonesia, biplot analysis is an effective way to visualize the relationship between observed objects (provinces) and variables (risk factors) in the form of a two-dimensional diagram (Saputri, Salma, Amalita, & Permana, 2024). In the context of spatial mapping of DHF incidence in Indonesia, biplot analysis can be used to identify areas with high DHF incidence and find patterns of DHF spread in various regions. For example, Muhammad et al (2020) used biplot analysis to map hepatitis disease types in districts or cities in East Java. This shows that biplot analysis can identify patterns of disease spread.

The application of biplot analysis in public health in Indonesia has provided promising results and has advantages in presenting information on research objects (Lestanto & Pramaputri, 2021). For example, Juwita et al (2021) used biplot analysis to identify spatial patterns and characteristics of sub-districts in Pekanbaru related to risk factors for tuberculosis disease and showed the effectiveness of this method in mapping areas based on the proximity of distance between objects. In addition, Hidayati et al (2023) highlighted the importance of spatial analysis on the incidence of dengue fever in Bantul Regency, which can be improved by using a biplot analysis approach. This research can also help in the development of more effective dengue management strategies, such as mosquito nest eradication and improved environmental hygiene.

Given the successful application of this method in previous studies and the need for a more comprehensive understanding of the factors affecting DHF at the provincial level, the research conducted is the application of biplot analysis to map the incidence of DHF to identify its spatial distribution pattern in Indonesia. The results of this study are expected to make a significant contribution to dengue control efforts in Indonesia through comprehensive mapping of risk factors based on the characteristics of each province.

II. METHODS

This study uses 2022 cross-section data from 34 provinces in Indonesia sourced from the Indonesian Central Bureau of Statistics and the Ministry of Health of the Republic of Indonesia. This research dataset, consists of six columns: Province, Average Temperature (X_1), Total Rainfall (mm/year) (X_2), percentage of Households with Proper Sanitation (X_3), Average Humidity (%)(X_4), dan and Number of DHF Patients (X_5). The steps in biplot analysis are as follows.

Create descriptive statistics of the data on factors affecting the incidence of Dengue Fever (DHF) to get an overview of the distribution of variables (X_1), (X_2), (X_3), (X_4) dan (X_5) in Indonesia
Performing singular value decomposition The singular value decomposition is the basis for biplot analysis, where the matrix $X_{n\times p}$ is split into three matrices $U, L^{1-\alpha}$ and $V,$ so that the SVD equation can be written:

$$X = UL^{1-\alpha}V' \quad (1)$$

The diagonal of matrix L is the non-zero eigenvalue (λ), of $X'X$, and the columns of V are the feature vectors corresponding to the eigenvalues. The columns of matrix U are obtained from Eq:

$$U_k = \frac{1}{\lambda_k} XV_k; k = 1,2,\dots,r \quad (2)$$

If $G = U$ and $H = L^{1-\alpha}V'$ are defined, then equation (1) can be written

$$Z = GH$$

And the ij-th element and X can be written as:

$$X_{ij} = g_i' h_j, i = 1,2,\dots,n, j = 1,2,\dots,n$$

where g_i' and h_j are the rows of G and H that have r elements.

Calculate the feasibility measure of the biplot by calculating the proportion of the 2 largest eigenvalues compared to the sum of all eigenvalues. Decomposing the single values in the X matrix, through the construction of biplots performed by creating G and H matrices Visualize biplot results and interpret them.

III. RESULTS AND DISCUSSION

3.1. Descriptive Statistics

Variable	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
X_1	24.99	27.43	28.18	28.00	28.59	29.41
X_2	879.4	2320.6	2786.2	2802.3	3245.7	4650.9
X_3	54.70	84.12	89.30	86.62	93.28	100.00
X_4	73.66	77.86	79.92	80.40	83.51	86.33
X_5	96	1093	2185	4214	4502	36608

Based on the descriptive statistics obtained, the Average Temperature variable (X_1) has a minimum value of 24.99°C and a maximum of 29.41°C, with an average of 28.00°C, indicating a fairly narrow temperature range in Indonesia. Total Rainfall (X_2) varies significantly, with a minimum rainfall of 879.4 mm/year to a maximum of 4650.9 mm/year, and an average of 2802.3 mm/year, reflecting the high climatic variation in different regions. Percentage of Households with Proper Sanitation (X_3) shows relatively high values, with an average of 86.62% of households having proper sanitation, although there is variation from 54.70% to 100%. Average Humidity (X_4) ranged from 73.66% to 86.33%, with an average of 80.40%. Finally, the Number of DHF Patients (X_5) varied widely, ranging from 96 to 36608 cases, with an average of 4214 cases, underscoring the differences in dengue disease burden across Indonesia.

3.2. Singular Value Decomposition

Based on the help of RStudio software, the singular value decomposition in the biplot analysis of the $n \times r$ matriks X is obtained into an $n \times r$ U, and $r \times r$ matriks L and an $r \times r$ matriks A, which can be written as:

$$X_{(34\times5)} = U_{(34\times5)}\, L_{(5\times5)} A'_{(5\times5)}$$

$$U = \begin{bmatrix} -0,161247136 & 0,111690661 & 0,19004515 & -0,15700838 & 0,09743174 \\ -0,123310509 & -0,095225438 & -0,09606433 & -0,17972564 & -0,06074271 \\ 0,112360395 & 0,031064968 & 0,13416559 & 0,03278807 & 0,13276754 \\ -0,192480457 & -0,058233287 & -0,07191464 & -0,02239726 & 0,14522289 \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ 0,146513124 & 0,104213731 & 0,06062857 & 0,18590277 & -0,09315209 \\ 0,003575524 & 0,094810858 & -0,30095589 & 0,01255009 & -0,05335313 \\ 0,181959183 & 0,08951167 & -0,06115275 & 0,18922912 & -0,05489449 \\ 0,128054231 & 0,232270165 & 0,19794282 & 0,06058209 & -0,16923515 \\ 0,178907208 & 0,357393975 & -0,13567792 & -0,26848155 & 0,01081841 \end{bmatrix}$$

$$L = \begin{bmatrix} 7.437893 & 0.000000 & 0.000000 & 0.000000 & 0.000000 \\ 0.000000 & 6.911915 & 0.000000 & 0.000000 & 0.000000 \\ 0.000000 & 0.000000 & 5.606138 & 0.000000 & 0.000000 \\ 0.000000 & 0.000000 & 0.000000 & 4.426027 & 0.000000 \\ 0.000000 & 0.000000 & 0.000000 & 0.000000 & 3.299196 \end{bmatrix}$$

$$A = \begin{bmatrix} 0.27471972 & -0.6336519 & 0.1410787 & -0.63777643 & -0.3104068 \\ -0.66351771 & 0.1827055 & -0.2201724 & -0.19295262 & -0.6638195 \\ 0.01239225 & -0.3673953 & -0.9112471 & 0.08960626 & 0.1626859 \\ -0.24849668 & -0.6156766 & 0.2736206 & 0.66501668 & -0.2051250 \\ 0.64989935 & 0.2259800 & -0.1624238 & 0.32516772 & -0.6280512 \end{bmatrix}$$

3.3. Biplot Feasibility Measures

The biplot feasibility measure is used as an important indicator in multivariate analysis that measures how well the biplot represents the original data in a lower-dimensional space. The feasibility measure uses the eigenvalue of each variable with the help of RStudio software. The following eigenvalues are obtained from each variable.

$$E = \begin{bmatrix} 55,32225 \\ 47,77457 \\ 31,42878 \\ 19,58971 \\ 10,88469 \end{bmatrix}$$

The biplot feasibility measure is obtained by calculating the proportion of the 2 largest eigenvalues compared to the sum of all eigenvalues. The values obtained are λ_1 = 55,32225, λ_2 = 47,77457, λ_3 = 31,42878, λ_4 = 19,58971 and λ_5 = 10,88469 so that the value of ρ^2 is obtained:

$$\rho^2 = \frac{(\lambda_1 + \lambda_2)}{\sum_{k=1}^{14} \lambda_k} = \frac{55,32225 + 47,77457}{165} = 0.6248$$

Based on the calculation value above, the ρ^2 value obtained is 0,6248 so the resulting biplot is good enough, which means that the information provided by the biplot is 62,48% of the overall information obtained in the data.

3.4. Biplot Construction

After decomposing the singular values in the X matrix, biplot construction is carried out by creating G and H matrices using $\alpha = 1$ then $G = UL$ and $H' = A$. The G^* and H^* matrix obtained using RStudio software are as follows:

$$G^* = \begin{bmatrix} -0,439761252 & 0,293640564 \\ -0,336298587 & -0,250352636 \\ 0,306434889 & 0,081671418 \\ -0,524942328 & -0,153098345 \\ \vdots & \vdots \\ \vdots & \vdots \\ 0,009751348 & 0,249262683 \\ 0,496248184 & 0,235330843 \\ 0,349235902 & 0,610650358 \\ 0,487924685 & 0,939607369 \end{bmatrix}$$

$$H^* = \begin{bmatrix} 0,74922936 & -1,809579 & 0,0337968 & -0,6777126 & 1,7724380 \\ -1,665904 & 0,4803423 & -0,9659013 & -1,6186459 & 0,5941132 \end{bmatrix}$$

3.5. Biplot Analysis Results

The following are the results of data visualization formed in the biplot analysis of health indicators in Indonesia based on provinces in Indonesia using RStudio software show on Figure 1.

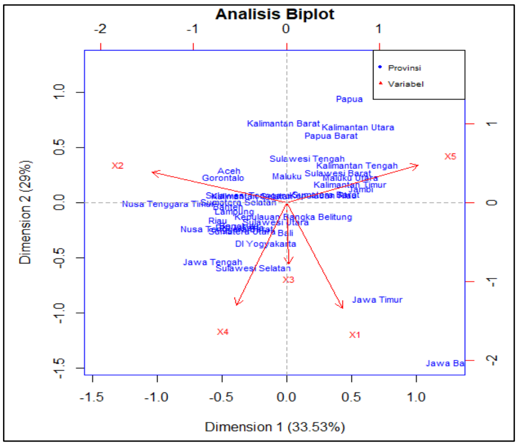

Figure 1. Biplot Mapping of Factors Influencing DHF in Indonesia in Indonesia

Based on the data visualization in the form of a biplot graph above, the following information is obtained:

a. *Proximity Between Objects*

The analysis of proximity between objects on the biplot explains the similarity of characteristics between provinces. Provinces located in the same quadrant show similar characteristics. Quadrant IV is the quadrant with the highest number of DHF cases which includes provinces such as East Nusa Tenggara, Banten, Lampung, North Sulawesi, Riau, West Nusa Tenggara, Bengkulu, North Sumatra, DKI Jakarta, Bali, Yogyakarta, Central Java, and South Sulawesi. Descriptively, the number of DHF cases in this quadrant reached 56,388 cases. The provinces in this quadrant have similar characteristics, especially in terms of average air humidity. This similarity in humidity is indicated to contribute to the high number of DHF cases in these areas.

b. *Variability Between Variables*

The characteristics between variables are used to see the diversity of characteristics in each province in Indonesia. Figure 1 shows that the variable with the longest vector, Number of Dengue Fever patients (X_5) varies significantly between provinces, indicating that there are areas with very high dengue cases and other areas with far fewer cases. This difference may be due to variations in the quality of health services or environmental conditions. In contrast, the variable with the shortest vector, Percentage of Households with Proper Sanitation (X_3) indicates a more even distribution of households with proper sanitation. Descriptively, the average percentage of households with proper sanitation in Indonesia is 86.62%, and this figure tends to be consistent across provinces.

c. *Correlation between Variables*

The vectors of variables X_2 and X_4 , X_1 and X_5 orm an angle close to 90°, indicating that these two variables have no significant relationship or a weak correlation. Meanwhile, the vectors of variables X_1 and X_4, X_1 and X_3, X_3 and X_4 form an angle of less than 90°, indicating a positive correlation between the two variables. In contrast, the vectors of variables X_2 and X_3, X_3 and X_5, X_1 and X_2, X_4 and X_5, X_2 and X_5 form an angle greater than 90°, indicating a negative correlation between the variables.

d. *Key Characteristics of Each Object*

East Java province is located in the same direction as vector X_1, which indicates that the characteristics represented by variable X_1 ave a high value in East Java province. Papua and West Java provinces are far from all variable vectors, indicating that the value of characteristics in these provinces is relatively lower than other provinces. Aceh and Gorontalo provinces are located in the same direction as the X_2 vector, indicating that the characteristics measured by the X_2 variable have high values in both provinces. The provinces of Bangka Belitung Islands and Bali are located in the same direction as vector X_3 indicating that the characteristics measured by variable X_3 have high values in both provinces. Furthermore, the provinces of North Sulawesi, DI Yogyakarta, Central Java and South Sulawesi are located in the same direction as vector X_4 indicating that the characteristics measured by variable X_4 have high values in these provinces. On the other hand, the provinces of Central Kalimantan, West Sulawesi, North Maluku, East Kalimantan and Jambi are located close to and in the same direction as vector X_5, indicating that the characteristics measured by variable X_5 have high values in these provinces.

IV. CONCLUSIONS

Based on the application of biplot analysis, it can be concluded that the spatial distribution pattern of DHF incidence in Indonesia shows significant variation between provinces. Quadrant IV, which includes 13 provinces that show the highest number of DHF cases descriptively with a total of 56,388 cases, is associated with similar air humidity characteristics. Meanwhile, the percentage of households with proper sanitation is relatively uniform across Indonesia. Descriptively, the average decent sanitation is 86.62%, indicating success in equalizing efforts to improve decent sanitation in Indonesia. Furthermore, variables X_2 and X_4 , X_1 and X_5, form an angle close to 90°, indicating a weak correlation. In contrast, the variables X_1 and X_4, X_1 and X_3, X_3 and X_4 show angles less than 90°, indicating a positive correlation. Meanwhile, the variables X_2 and X_3, X_3 and X_5, X_1 and X_2, X_4 and X_5, X_2 and X_5 orm an angle of more than 90, indicating a negative correlation. Finally, East Java has high values for characteristic X_1, while Papua and West Java have low values for all variables. Aceh and Gorontalo, in the direction of X_2, and Bangka Belitung Islands and Bali, in the direction of X_3, show high values for the corresponding variables. North Sulawesi, DI Yogyakarta, Central Java and South Sulawesi have high values for X_4, while Central Kalimantan, West Sulawesi, North Maluku, East Kalimantan and Jambi show high values for X_5.

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