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Application of correspondence analysis on the spread of foot and mouth disease in cattle in East Java, Indonesia

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Abstract

Objective: This study aims to apply correspondence analysis to map the cases of Foot and Mouth Disease (FMD) in cattle across East Java. The primary objective is to identify the patterns of spread and severity of FMD cases by categorizing each case based on criteria of death, forced culling, and illness across various districts and cities in East Java.

Method: The data used in this study were obtained from reports by the Livestock Department, which recorded incidents of FMD in various districts and cities in East Java. After data collection, the data were processed using correspondence analysis with the help of SPSS software version 27. Through this method, we aim to identify and visualize the relationships between the location of the incidents and the three response categories of cases: death, forced culling, and sickness.

Results: The results of the correspondence analysis showed that the proportion of cattle deaths due to FMD was the highest, followed by forced culling actions and sickness cases. Data visualization indicated specific patterns of distribution and severity of FMD that varied between different districts and cities in East Java. Some locations showed higher death incidents, while in other locations, cases of sickness or forced culling were more predominant.

Conclusion: Correspondence analysis successfully grouped the FMD cases in cattle in East Java based on the criteria of death, forced culling, and sickness. This study provides significant insights regarding the geographic distribution and response variability to the FMD outbreak in East Java. With this understanding, strategic and location-specific steps can be taken to eradicate FMD, including increased vigilance, resource allocation for medical actions, and more effective disease control policies in the most affected areas. This research demonstrates the importance of in-depth data analysis in addressing disease outbreaks in the livestock sector, thus facilitating more informed and effective decision-making in efforts to combat the disease.

Keywords: FMD; East Java; Correspondence analysis; Cattle; Distribution.

1. Introduction

The resurgence of Foot and Mouth Disease (FMD), especially after Indonesia was declared free from the disease, has added to the unrest in Indonesia (Ministry of Agriculture Decree No.260/Kpts/TN.510/5/1986). This concern is due to the infectious nature of FMD, its widespread distribution, and in some cases, its lethality. Thirty years after the eradication of FMD, precisely on April 28, 2022, FMD reappeared starting from Gresik. Shortly thereafter, on May 2 of the same year, cases of FMD were found in the districts of Lamongan, Sidoarjo, and Mojokerto [1, 2, 3]. The mapping of

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FMD cases in Indonesia as of December 13, 2022, shows that most of the islands of Java, Bali, Lombok, West Nusa Tenggara, and East Nusa Tenggara are positive for FMD. The spread of FMD in Sumatra has reached 90 percent of the island's area, while in Kalimantan, due to the lack of widespread spread, the distribution of FMD is not as uniform as on Java or Sumatra [4]. The count of the cattle population affected by FMD in Indonesia shows that East Java ranks first, followed by West Nusa Tenggara, while West Sulawesi is at the bottom[5].

The cause of FMD is the genus Aphthovirus of the family Picornaviridae, discovered by Loeffler 400 years (1897) after the FMD outbreak. This virus has five serotypes; serotype O is found in almost all countries except Oceania, North and Central America, and the Caribbean, where there was no outbreak at the time. Conversely, serotype Asia 1 is only found in Asia. Serotype C is not found in Asia but is found in Europe, Africa, and South America [6]. FMD entered Indonesia in 1887 in Malang. The main factor for the introduction of FMD into Indonesia is livestock traffic. From Malang, FMD spread to Banyuwangi in 1889; cases of FMD were reported in Jakarta, followed successively by Aceh and Sumatra (1892), Madura and Kalimantan (1906), and Sulawesi in 1902, West Nusa Tenggara (1911), and Bali [7]. In 1980, FMD was no longer found, and Indonesia was declared free in 1984. However, in the same year, an outbreak of FMD occurred in Blora. From Blora, FMD spread west to Banten and only reached the border of Central Java - East Java [8].

Transmission of FMD to humans has never been reported. This does not mean that FMD is not transmissible to humans. Transmission of FMD to humans occurs through consuming unpasteurized livestock products such as meat or milk (rapid risk assessment, 2012). Symptoms of FMD in humans include weakness, fever, vomiting, and red wounds in the oral tissue or vesicular lesions on the skin [9]. The impact of the FMD outbreak on society can include psychological effects, especially economic impacts. The psychological impact, such as fear of contracting FMD from consuming animal products such as milk or meat, also affects the economy, especially for business owners, in the form of decreased income due to reduced demand. For dairy cattle farmers, for example, the FMD outbreak causes a decrease in milk production which affects income, and this decrease continues for some time after the cattle recover from FMD. To anticipate production costs, farmers choose to sell their livestock [10]. For the country, an FMD outbreak requires additional costs that may be obtained from reducing other projects [11, 12].

In response to the outbreak situation in Indonesia, the government through the Minister of Agriculture, besides setting regulations related to FMD issues, takes actions such as providing donations to the farming community, cooperating with the community to inspect sacrificial animals [13, 14]. Media is another factor that needs to be considered in taking action against the control or prevention of the spread of the FMD outbreak. The media presents information in the form of photos of events, activities, or data tables, graphs, or maps. One tool used to present information in the form of maps is correspondence analysis. Correspondence analysis analyzes the relationship between two or more categorical data variables in the form of frequency. The results of the analysis are presented in the form of a target variable map, and the closeness of the relationship is reviewed from the distance between variables.

2. Material and methods

This method provides a robust framework for analyzing categorical data related to FMD in East Java. By utilizing Correspondence Analysis, this research successfully mapped the distribution and severity of the disease across different regions, offering essential insights for policymakers and health officials in designing more effective control measures. This methodology emphasizes not only the distribution and impact of FMD but also highlights the potential of advanced statistical tools in epidemiological investigations, enabling more informed and effective decision-making in efforts to eradicate the disease.

The data used in this study were sourced from reports issued by the East Java Department of Livestock. These reports include information about the incidents of Foot and Mouth Disease (FMD) that occurred across various districts and cities within East Java. The information collected comprises the locations of the incidents, the number of cases reported, and the final outcomes of each case, namely death, forced culling, or illness.

The collected data were then processed to ensure accuracy and consistency. This step includes verifying data completeness, handling missing values, and standardizing the format of the data to be analyzed. This data preparation step is crucial to ensure that the subsequent analysis can be conducted effectively and to reduce potential biases caused by data inconsistencies.

Following data preparation, correspondence analysis was conducted using SPSS software version 27. Correspondence analysis is a multivariate statistical technique used to analyze relationships within categorical data and provide a graphical visualization of these data, allowing for more intuitive identification of patterns and relationships among

variable categories. In this context, the analysis was conducted to examine the relationships between the locations of FMD incidents and three outcome categories: death, forced culling, and sickness.

2.1. Analytical Process

All categorical data, including locations and case outcomes, were accurately coded. Locations were coded based on their administrative identification, and case outcomes were categorized into one of the three predetermined categories. The analysis was executed by plotting the frequencies of FMD case outcomes against geographical locations in a two-dimensional plot. This helps in visualizing how the distribution and outcomes of cases relate to geographical locations.

On the correspondence analysis plot, the axes represent dimensions that explain the maximum variability in the data. The proximity between points on the plot indicates a stronger relationship between categories, helping to identify which case outcomes are more common in specific locations. To ensure the reliability of the findings, the analysis was supplemented with additional statistical testing such as the chi-square test to confirm the presence or absence of independent relationships between categorical variables.

The results from the correspondence analysis were then visualized using biplots and interpreted to identify significant patterns and trends. These visualizations greatly assist stakeholders in quickly understanding complex relationships and facilitate strategic discussions regarding the management of the FMD outbreak.

3. Results

The chi-square analysis shows a relationship between cities with prevalent FMD and cattle status (sick, dead, or forced culling) ($p < 0.001$). The relative frequency of cattle death was the highest (0.573), followed by sickness (0.080) and forced culling (0.348). In correspondence analysis, the relative frequency is termed 'Mass' [15]. The interaction of death mass with regions in East Java revealed that districts such as Banyuwangi, Blitar, Gresik, Jember, Kediri, Kota Madya Blitar, Madiun, Malang, Pasuruan, Probolinggo, Lamongan, Lumajang, Magetan, and Trenggalek have a higher relative frequency compared to cattle that are sick or culled. Areas such as Jombang, Kota Madya Batu, Mojokerto, Surabaya, Pasuruan, Sidoarjo fall into the group where the relative frequency of forced culling is higher than the other two statuses. Forced culling status ranks lower than death status. Sick status is found among cattle in districts like Bangkalan, Bondowoso, Kota Madya Kediri, Pacitan, and Sumenep.

Table 1 Row Profiles of FMD Incidents in East Java Propensity

District-city	Status			
	Sick	Death	Forced cutting	Active Margin
Bangkalan	0.267	0.584	0.149	1.000
Banyuwangi	0.010	0.394	0.596	1.000
Blitar	0.009	0.929	0.062	1.000
Bojonegoro	0.000	0.833	0.167	1.000
Bondowoso	0.169	0.310	0.520	1.000
Gresik	0.000	0.996	0.004	1.000
Jember	0.000	1.00	0.000	1.000
Jombang	0.122	0.275	0.603	1.000
Kediri	0.090	0.848	0.062	1.000
Kota Batu	0.000	0.415	0.585	1.000
Kota Blitar	0.000	0.950	0.050	1.000
Kota Kediri	0.500	0.188	0.313	1.000
Kota Madiun	0.000	0.880	0.120	1.000
Kota Malang	0.000	0.657	0.343	1.000

Kota Mojokerto	0.082	0.357	0.561	1.000
Kota Pasuruan	0.000	0.923	0.077	1.000
Kota Probolinggo	0.071	0.842	0.087	1.000
Kota Surabaya	0.000	0.469	0.531	1.000
Lamongan	0.044	0.765	0.191	1.000
Lumajang	0.016	0.879	0.104	1.000
Madiun	0.000	1.00	0.000	1.000
Magetan	0.000	1.00	0.000	1.000
Malang	0.000	0.091	0.909	1.000
Mojokerto	0.000	0.018	0.982	1.000
Nganjuk	0.000	0.000	0.000	0.000
Ngawi	0.000	0.000	1.00	1.000
Pacitan	0.226	0.645	0.129	1.000
Pamekasan	0.000	0.000	0.000	0.000
Pasuruan	0.000	0.583	0.417	1.000
Ponorogo	0.114	0.616	0.269	1.000
Probolinggo	0.000	0.000	0.000	0.000
Sampang	0.152	0.489	0.359	1.000
Sidoarjo	0.080	0.457	0.464	1.000
Situbondo	0.385	0.241	0.374	1.000
Sumenep	0.629	0.292	0.079	1.000
Trenggalek	0.000	0.918	0.082	1.000
Tuban	0.000	0.686	0.314	1.000
Tulungagung	0.000	0.279	0.721	1.000
Mass	0.080	0.573	0.348	

Table 2 Profiles Line

District-city	**Status**			
	Sick	**Death**	**Forced cutting**	**Mass**
Bangkalan	0.211	0.064	0.027	0.063
Banyuwangi	0.019	0.109	0.273	0.159
Blitar	0.003	0.046	0.005	0.029
Bojonegoro	0.000	0.012	0.004	0.008
Bondowoso	0.067	0.017	0.047	0.031
Gresik	0.000	0.051	0.000	0.029
Jember	0000	0.002	0.000	0.001
Jombang	0.025	0.008	0.029	0.017

Kediri	0.021	0.027	0.003	0.018
Kota Batu	0.000	0.011	0.025	0.015
Kota Blitar	0.000	0.004	0.000	0.003
Kota Kediri	0.025	0.001	0.004	0.004
Kota Madiun	0.000	0.010	0.002	0.006
Kota Malang	0.000	0.046	0.040	0.040
Kota Mojokerto	0.013	0.008	0.020	0.012
Kota Pasuruan	0.000	0.061	0.008	0.038
Kota Probolinggo	0.021	0.034	0.006	0.023
Kota Surabaya	0.000	0.057	0.107	0.070
Lamongan	0.005	0.012	0.005	0.009
Lumajang	0.029	0.213	0.042	0.139
Madiun	0.000	0.000	0.000	0.000
Magetan	0.000	0.001	0.000	0.001
Malang	0.000	0.002	0.026	0.010
Mojokerto	0.000	0.001	0.060	0.021
Nganjuk	0.000	0.000	0.000	0.000
Ngawi	0.000	0.000	0.001	0.000
Pacitan	0.011	0.004	0.001	0.004
Pamekasan	0.000	0.000	0.000	0.000
Pasuruan	0.000	0.014	0.016	0.014
Ponorogo	0.049	0.037	0.027	0.034
Probolinggo	0.000	0.000	0.000	0.000
Sampang	0.022	0.010	0.012	0.012
Sidoarjo	0.111	0.089	0.149	0.111
Situbondo	0.165	0.014	0.037	0.034
Sumenep	0.202	0.013	0.006	0.026
Trenggalek	0.000	0.010	0.001	0.006
Tuban	0.000	0.008	0.006	0.006
Tulungagung	0.000	0.003	0.011	0.005

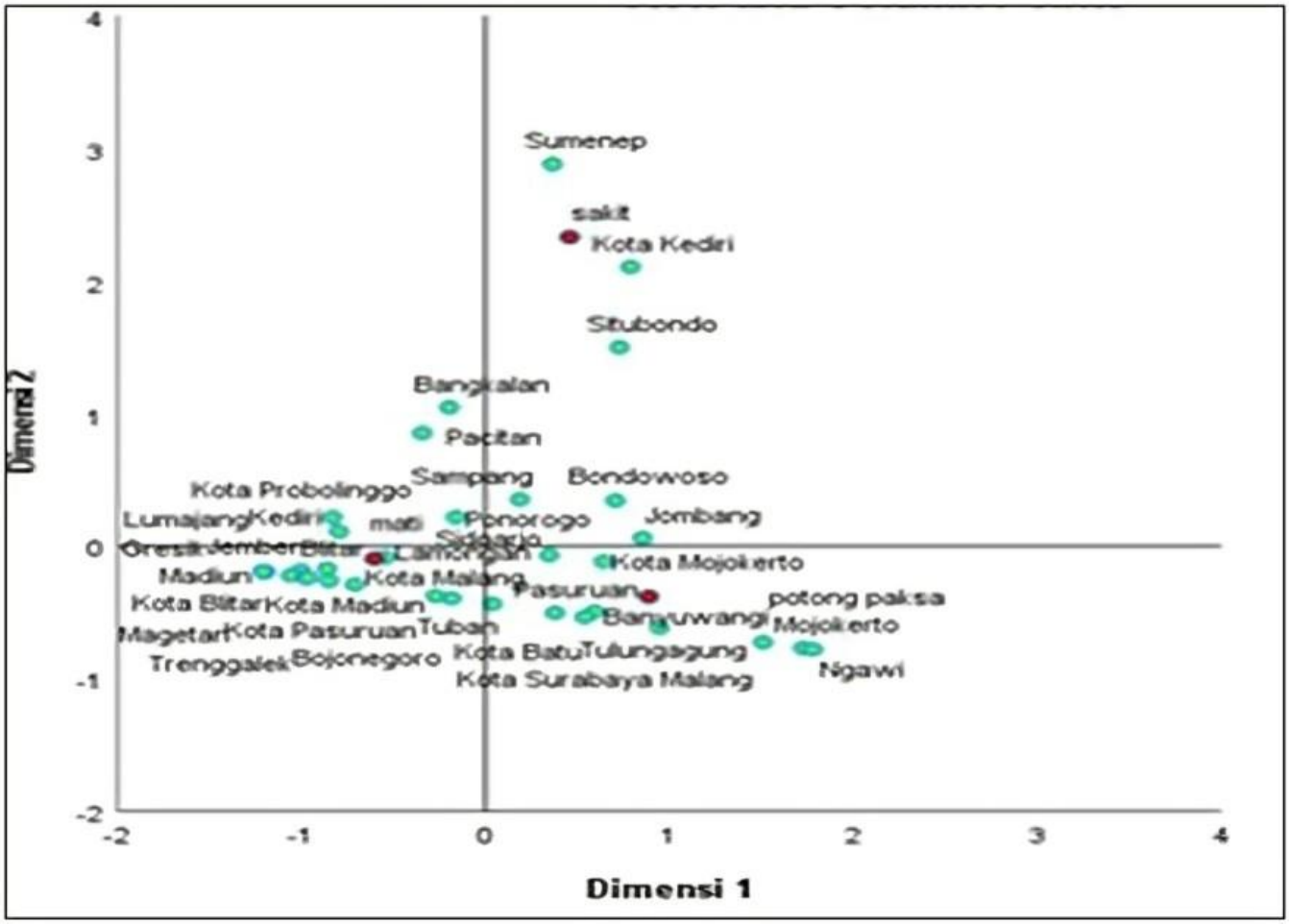

Figure 1 Relationship of districts and cities in East Java with respect to the impact of FMD in August 2025

A teal circle indicates districts and cities affected by FMD. A red circle indicates the impact or activities during the FMD outbreak. The teal circle represents areas in East Java heavily affected by FMD. The priority status is determined by the distance between the most affected cities and their status. A comparison of the relative frequencies of the most affected areas is conducted after weighting the status by the mass of each area.

Suppose each dimension is divided into two, then the map field has four sections (quadrants). Connecting the variable of districts and cities with death, there appears to be a density distribution of districts and cities surrounding the status of death. This indicates that deaths, due to FMD in the districts and cities of East Java, are the primary focus of attention. This is consistent with Table 1 where the death score ranks the highest. The second rank is occupied by activities involving forced culling of cattle and the last is found in cases of sick cattle due to FMD.

4. Discussion

Correspondence analysis was discovered by Herman Otto Harley and later developed by Jean Paul Benzecry. Nowadays, correspondence analysis is widely used in various sciences such as the structure of amino acids composing proteins (molecular field, Camproux and Tuffery, 2005), research in psychology [16], or medical science [17]. The analysis shows that there is a relationship between the status of FMD and the districts and cities in East Java. The three statuses analyzed are almost found in all districts and cities with diverse compositions. Death and sickness are factors that potentially cause more damage in Indonesia, where many smallholder cattle farms are still prevalent. Smallholder cattle farming is characterized by generally no more than three cattle, part-time work, and a familial atmosphere [18, 19]. Such nature results in a lack of information related to livestock farming efforts received [20].

Generally, FMD has a low mortality rate (0.8 percent), but from the analysis, a high relative frequency of cattle deaths was found in 16 districts compared to incidents of sickness or forced culling (Table 1 and Figure 1) [21]. The relative frequency of forced culling and sickness ranks second and third after death. Forced culling activities are spread across

nine districts and cities in East Java. Forced culling is an action taken to prevent the widespread spread of the disease and is carried out on cattle with little hope of recovery [22]. Apart from forced culling, the spread of FMD can also be prevented through methods such as vaccination, restriction of animal traffic, and biosecurity [23]. Due to the rapid spread of FMD and the significant impact, especially economic losses in all economic sectors, FMD has now become a national issue. In connection with this, the government is organizing strategies in the effort to eradicate FMD that involves related sectors through circular letter number 05254/SE/PK.300/F/05/2022. One of the purposes of this circular letter is the collection of FMD data as a consideration for devising strategies to eradicate FMD.

5. Conclusion

Correspondence analysis groups the FMD events in the districts and cities of East Java into three statuses. The grouping of statuses is based on the highest relative frequency of FMD cases in each district and city. The highest relative frequency is found in death cases spread across fourteen districts and cities in East Java, followed by statuses of forced culling and sickness.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

Statement of ethical approval

The study was approved by the Faculty of Veterinary Medicine Animal Ethics Committee of Universitas Airlangga. All variables were considered in accordance with the Ethics Committee related to the animal handling to ensure no discomfort or pain was caused to the animals during sampling.

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