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SPATIAL MAPPING AND RISK STRATIFICATION OF RABIES CASES USING GEOGRAPHIC INFORMATION SYSTEM (GIS) IN SIKKA REGENCY, EAST NUSA TENGGARA PROVINCE

Pemetaan Spasial dan Stratifikasi Risiko Kasus Rabies Berbasis Sistem Informasi Geografis (SIG) di Kabupaten Sikka, Provinsi Nusa Tenggara Timur

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Abstract

Rabies remains a significant zoonotic disease and a major public health concern in Sikka Regency, East Nusa Tenggara Province, Indonesia, due to the high dog population, low vaccination coverage, and free-roaming dog management practices in the region. This study aimed to map the spatial distribution of rabies cases using a geographical information system (GIS) to identify high-risk areas and support the development of effective control strategies. A quantitative descriptive study with a spatial approach was conducted using geographic information systems (GIS). Secondary data on rabies cases reported during 2023–2024 were obtained from the Department of Agriculture of Sikka Regency and analyzed through spatial mapping, buffer analysis of health service facilities, and regional stratification based on the rabies status. The results showed that in 2023, rabies cases were distributed across 15 subdistricts, comprising 39 case locations and 66 laboratory-confirmed specimens. In 2024, the distribution expanded to 17 subdistricts, with 33 case locations and 41 positive samples. Although the affected area increased, the number of cases and positive specimens declined, which reflects the effectiveness of intensified local control measures. Buffer analysis demonstrated that most case locations were within the service coverage of health facilities, whereas regional stratification successfully classified areas into rabies-free and rabies-infected zones to support priority setting for interventions. In conclusion, GIS is an effective tool for visualizing the spatial distribution of rabies and provides valuable information for surveillance,

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vaccination planning, and evidence-based rabies control in Sikka Regency. Regular updates of GIS-based surveillance integrated with the One Health approach are recommended to strengthen sustainable rabies prevention and elimination programs.

Keywords: geographical information system (GIS), rabies, regional stratification, Sikka Regency spatial mapping

Abstrak

Rabies merupakan penyakit zoonosis yang masih menjadi masalah kesehatan masyarakat di Kabupaten Sikka, Provinsi Nusa Tenggara Timur, karena tingginya populasi anjing, rendahnya cakupan vaksinasi, dan pola pemeliharaan anjing yang masih dilepasliarkan. Penelitian ini bertujuan untuk memetakan persebaran kasus rabies menggunakan *Geographical Information System* (GIS) sehingga dapat mengidentifikasi wilayah berisiko serta mendukung penyusunan strategi pengendalian yang lebih efektif. Penelitian menggunakan metode deskriptif kuantitatif dengan pendekatan spasial berbasis GIS. Data sekunder berupa kasus rabies tahun 2023–2024 diperoleh dari Dinas Pertanian Kabupaten Sikka dan dianalisis melalui pemetaan sebaran kasus, analisis buffer terhadap fasilitas pelayanan kesehatan, serta stratifikasi wilayah berdasarkan status rabies. Hasil penelitian menunjukkan bahwa pada tahun 2023 kasus rabies tersebar di 15 kecamatan dengan 39 lokasi kasus dan 66 spesimen positif, sedangkan pada tahun 2024 penyebaran meluas menjadi 17 kecamatan dengan 33 lokasi kasus dan 41 spesimen positif. Meskipun wilayah terdampak bertambah, jumlah kasus dan spesimen positif mengalami penurunan yang diduga merupakan hasil dari intensifikasi upaya pengendalian di tingkat lokal. Analisis buffer menunjukkan bahwa sebagian besar lokasi kasus masih berada dalam jangkauan fasilitas pelayanan kesehatan, sedangkan analisis stratifikasi berhasil mengelompokkan wilayah ke dalam kategori bebas dan tertular rabies sebagai dasar penentuan prioritas intervensi. Pemanfaatan GIS efektif dalam menggambarkan distribusi spasial rabies serta mendukung perencanaan surveilans, vaksinasi, dan pengendalian rabies secara lebih tepat sasaran di Kabupaten Sikka. Oleh karena itu pemetaan berbasis GIS diperbarui secara berkala dan diintegrasikan dengan program surveilans serta pendekatan One Health untuk memperkuat upaya eliminasi rabies.

Keywords: *Geographical Information System* (GIS), Kabupaten Sikka, pemetaan spasial, rabies, stratifikasi wilayah

INTRODUCTION

Rabies is a fatal viral zoonotic disease that affects the central nervous system of mammals and remains a public health concern in Sikka Regency (Khairullah *et al.*, 2023). Rabies is a zoonotic disease that remains a major risk to public and animal health worldwide, including in Indonesia (Jasape & Wahyono, 2025). The rabies virus belongs to the family Rhabdoviridae and genus *Lyssavirus*. A key characteristic of the virus is its single, non-segmented, negative-sense RNA strand. This virus resides in several animal species that act as transmission vectors, including raccoons, red foxes, and dogs. The disease targets the central nervous system of mammals and can spread through bites, scratches, or contact with the saliva of infected animals. Rabies has an extremely high fatality rate because nearly all patients who exhibit clinical signs cannot be saved. The high death rate from rabies makes this disease a priority in zoonotic disease control programs, particularly in endemic areas with high dog populations and low vaccination coverage (Kale *et al.*, 2025). Consequently, the World Health Organization (WHO) and the Indonesian government consider rabies a priority disease in zoonosis control programs (Mardiana *et al.*, 2025).

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The province of East Nusa Tenggara (NTT) is one of the rabies-endemic regions in Indonesia that continues to face challenges in controlling the disease (Jasape & Wahyono, 2025). Rabies cases in NTT are influenced by the high population of free-roaming dogs, low vaccination coverage among rabies-transmitting animals, shortage of vaccinators, and low public awareness of the importance of rabies prevention (Simarmata *et al.*, 2025). A recent study showed that during the 2023–2024 period, there were more than 50,000 cases of dog bites and more than 80 human deaths due to rabies in the NTT region (Kale *et al.*, 2025), making rabies a persistent and serious public health issue and challenge in the East Nusa Tenggara (NTT) Province, particularly in Sikka Regency.

Sikka Regency has a predominantly Roman Catholic population. This situation is believed to influence the community's dog-keeping practices, thereby contributing to the high dog population and rabies outbreaks (Klaudius *et al.*, 2021). Dog-keeping practices, which are still largely carried out traditionally through free-roaming, have the potential to increase contact between rabies-carrying animals, humans, and other animals (Safaldy *et al.*, 2021). Furthermore, the geographical characteristics of Sikka Regency, which consists of coastal areas, lowlands, and hills, can influence the pattern of disease spread across the regions. These conditions require a monitoring system capable of mapping the spatial distribution of cases so that high-risk areas can be identified quickly and accurately.

Previous research on rabies mapping in Sikka Regency conducted by Mau *et al.* (2011) showed that rabies cases were not evenly distributed but formed several clusters with varying risk levels. However, this study did not describe the spatial dynamics following the 2023–2024 rabies outbreak and did not include an analysis of health facility accessibility in its risk mapping analysis. The novelty of this study lies in the updated map of rabies distribution following the 2023–2024 outbreak and the integration of a buffer analysis of health facilities to evaluate service accessibility and support the identification of priority areas for rabies control.

Advances in information technology offer opportunities to improve the effectiveness of disease surveillance using geographic information systems (GIS). A GIS is a computer-based system capable of collecting, managing, analyzing, and visualizing geographically referenced data (Jia *et al.*, 2023). In the field of epidemiology, GIS is widely used to map disease distribution, identify high-risk areas, analyze environmental risk factors, and support decision-making in disease control programs. Through a GIS approach, information regarding the location of rabies cases can be presented in the form of easy-to-understand digital maps, thereby supporting more targeted intervention planning for rabies control.

Spatial mapping of rabies cases is becoming increasingly important because effective control strategies require the identification of priority areas based on the risk of disease spread. By understanding the geographic distribution patterns of cases, local governments can determine locations for mass dog vaccination campaigns, enhance public education in high-risk areas, and strengthen early warning systems for the potential emergence of new cases. Furthermore, the mapping results can serve as a foundation for supporting the One Health approach, which integrates human, animal, and environmental health in rabies control (Kale *et al.*, 2025). Based on the above, research on "Mapping Rabies Case Distribution Areas Using GIS Methods in Sikka Regency, East Nusa Tenggara Province" is necessary to obtain a spatial overview of rabies case distribution, identify high-risk areas, and provide scientific information that can be used as a basis for developing more effective and sustainable strategies for the prevention and control of rabies in the Sikka Regency.

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RESEARCH METHODS

Time and Location of the Study

This study was conducted from January to July 2026 in Sikka Regency, covering 15 subdistricts and 39 villages based on the 2023 rabies case distribution data and 17 subdistricts and 33 villages based on the 2024 rabies case distribution data.

Research Sample

The sample consisted of specimens that tested positive for rabies using a rapid test at the Animal Health Laboratory of the Sikka Regency Department of Agriculture. The research sample was selected using purposive sampling based on the inclusion criterion of rabies-positive specimens, thereby enabling the mapping of spatial patterns of case distribution using a Geographic Information System (GIS).

Research Methods and Type

This study employed a quantitative descriptive research method with a spatial approach based on a geographic information system (GIS) using ArcGIS v10.8 software. The research design was cross-sectional, meaning that rabies case data were collected during a specific period to describe the geographic distribution patterns of cases in Sikka Regency. The GIS approach was used to identify, visualize, and analyze the spatial distribution of rabies cases to identify areas with a higher risk of transmission.

Research Procedure

This study began with a preparatory phase that included determining the research location and timeline, as well as setting up ArcGIS v10.8 software used for data processing and analysis. Next, secondary data in the form of rabies case data was collected from the Sikka Regency Agriculture Office. The data collected included the number of cases, locations of occurrence, and dates of rabies cases in 2023 and 2024. In addition, spatial data in the form of an administrative map of Sikka Regency were collected and used as the basis for the mapping process.

The data on rabies-positive specimens that were obtained were then examined and verified to ensure their completeness and suitability for research needs. Subsequently, the data were entered into ArcGIS v10.8 and linked to spatial data based on the locations of the cases. This process aimed to generate spatial information that could illustrate the distribution of rabies cases across each administrative area in the Sikka Regency.

Data Analysis

The next step was spatial analysis using GIS methods to determine the distribution patterns of rabies cases in the province. The analysis involved mapping the locations of cases, grouping areas based on rabies incidence rates, and identifying areas with a higher risk of transmission. The results of the analysis are presented in the form of thematic maps, showing the distribution of rabies cases in Sikka Regency.

RESULTS AND DISCUSSION

Geographical Conditions

Sikka Regency is located in the eastern part of Flores Island in the East Nusa Tenggara Province. Sikka Regency covers an area of approximately 1,731 km² with varied topography, ranging from coastal areas and lowlands to hilly and mountainous regions. Most of the region

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has slopes of varying gradients, which influence land-use patterns, interregional accessibility, and population distribution (Sikka Regency Central Statistics Agency, 2024).

Geographically, Sikka Regency is located between 8°22'–8°50' South Latitude and 121°55'–122°41' East Longitude (Figure 1). It is bordered by the Flores Sea to the north, East Flores Regency to the east, Ende Regency to the west, and Sawu Sea to the south. Sikka Regency has a tropical climate with two seasons: rainy and dry. Rainfall and climatic conditions are influenced by the monsoon winds and geographical features of Flores Island. Air temperatures generally range from 22°C to 34°C, with relatively high humidity (Sikka Regency Central Statistics Agency, 2024).

Administratively, Sikka Regency consists of 21 sub-districts and 194 villages, with an archipelagic territory that includes several small islands along Flores' northern coast. The geographical conditions, comprising coastal areas, hills, and mountains, result in variations in transportation access and community mobility across regions. In epidemiological studies of diseases, including rabies, these geographic characteristics can influence the movement of rabies-carrying animals, distribution of cases, and effectiveness of vaccination and disease control programs (WHO, 2023).

Mapping of Rabies Cases

Figure 2 shows that the rabies cases in 2023 were spread across 15 sub-districts. A total of 39 cases were identified in several villages and urban neighborhoods, and 66 specimens were rabies-positive. The distribution of these cases indicates that rabies is not concentrated in a single area but has spread to nearly the entire Sikka Regency area.

In 2024, cases were reported in 17 subdistricts and 33 villages/neighborhoods, with 41 positive specimens. Although the affected area expanded from 15 to 17 subdistricts, there was an increase in the spread of positive rabies cases in new areas, namely, the Paga and Waiblama subdistricts. To date, the source of transmission has not been confirmed, but it is strongly suspected to originate from the districts of Waigete, Talibura, and Mego. The spread of rabies to these new areas is believed to have been triggered by the movement of dogs from infected areas to previously rabies-free areas by the community, as well as a dog-keeping system that still allows dogs to roam freely (unleashed), thereby increasing the risk of disease transmission. This incident strongly indicates that the containment of rabies-infected areas has not yet been fully and effectively implemented and that awareness among dog owners regarding the dangers of rabies remains low. If rabies outbreaks are not optimally controlled in a large animal population, the disease has the potential to spread rapidly and infect more rabies-carrying animals, particularly dogs (Dibia *et al.*, 2015).

The results of the buffer analysis (Figure 3) show that the distribution of health facilities in Sikka Regency can generally been able to reach most locations where rabies cases have occurred. The concentration of hospitals and community health centers in the central part of the regency results in more optimal health service coverage, as evidenced by the overlapping buffer zones at radii of 2, 4, and 8 km. Areas located within these intersecting buffer zones demonstrated better accessibility, as the community had alternatives to obtain services from more than one health facility according to their needs.

Geographic accessibility to healthcare facilities is a key factor influencing the speed at which people can obtain medical care after exposure to disease risks. In the case of rabies, easy access to community health centers or other healthcare facilities is critical for the timely treatment of victims of bites from rabies-carrying animals, including the administration of rabies vaccines (VAR). The closer health care facilities are to where people live, the greater the likelihood that

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they will be able to access health care quickly and effectively. Conversely, limited geographic access can lead to delays in treatment, potentially increasing the risk of rabies in humans (WHO, 2023).

As shown in Figure 4, the results of the 2024 rabies zone stratification showed that three additional subdistricts were classified as rabies zones: Paga, Waiblama, and Hewokloang. The Alok Timur Subdistrict was declared a rabies-free zone.

According to the data from 2023 and 2024, the Magepanda, Tanawawo, and Mapitara subdistricts are areas where no rabies cases have been detected and are therefore classified as rabies-free. On the map, areas classified as rabies-endemic are shown in yellow, areas classified as rabies-infected are shown in red, and rabies-free areas are shown in green.

According to a study conducted by Batan *et al.* (2014), uncontrolled populations of rabies-carrying animals are one of the factors contributing to the persistence of rabies in a given area. Dogs that are not properly cared for can transmit rabies to other animals and humans. This includes dogs that are not vaccinated, malnourished, do not receive proper nutrition, and are not kept clean enough. These conditions facilitate the spread of rabies (Kakang *et al.*, 2017).

The density of rabid dogs around residential clusters was significantly influenced by city area and average household size. In densely populated areas, the presence of stray animals (stray dogs and feral cats) is often higher because of the abundant access to food from household waste, minimal animal control, and intensive human–animal interaction (Tenzin *et al.*, 2012). In dense, uncontrolled populations, it is difficult to ensure optimal rabies vaccination coverage, thereby increasing the risk of transmission. The widespread practice of people excessively keeping and interacting with rabies-carrying animals poses a high risk of rabies bites (Chen *et al.*, 2019). Stray dogs or dogs of unknown ownership that roam markets, public places, beaches, and hills in search of food may also be at risk of exposure to rabies in unsanitary environments (Subrata *et al.*, 2020).

CONCLUSIONS AND SUGGESTIONS

Conclusions

Mapping the distribution of rabies cases using a geographic information system (GIS) can illustrate the spatial distribution patterns of cases and identify areas at risk of rabies. The mapping results can serve as a basis for determining priority areas and support the development of more targeted, effective, and area-based rabies-control strategies**.**

Suggestions

The Sikka Regency Agriculture and Health Offices are advised to prioritize mass vaccination of the canine population in areas identified as high-risk zones—particularly those located more than 8 km from health care facilities— to increase vaccination coverage, break the chain of transmission, and prevent the spread of rabies to surrounding areas. Future research should conduct a more specific cluster analysis of case density to identify areas with a significant concentration of rabies cases (high-risk clusters) as a basis for determining priority intervention areas. This analysis can also be integrated with factors such as dog population density, vaccination coverage, access to healthcare facilities, and environmental characteristics to produce a more comprehensive rabies risk map and support area-based control strategies for the disease.

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Figures

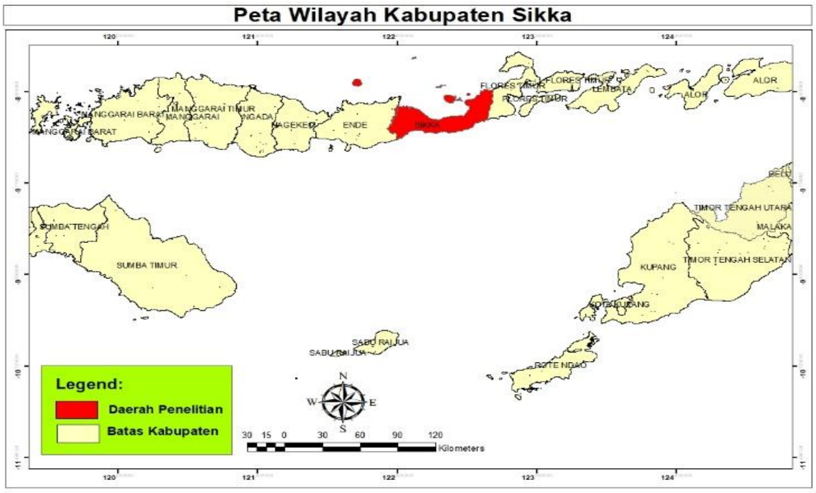

Figure 1. Map of Sikka Regency

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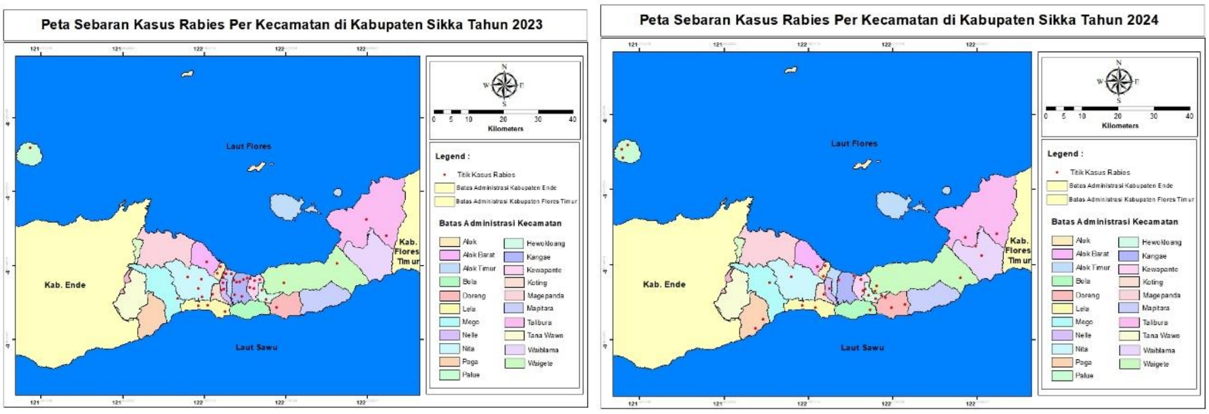

Figure 2. Map of Rabies Case Distribution by Subdistrict in 2023 and 2024

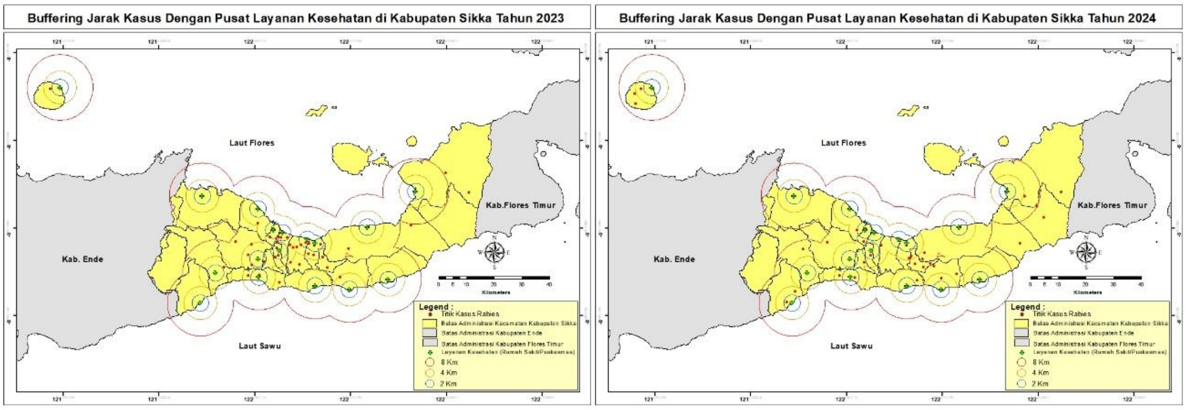

Figure 3. Map of Case-Distance Buffers Around Health Care Centers for 2023 and 2024

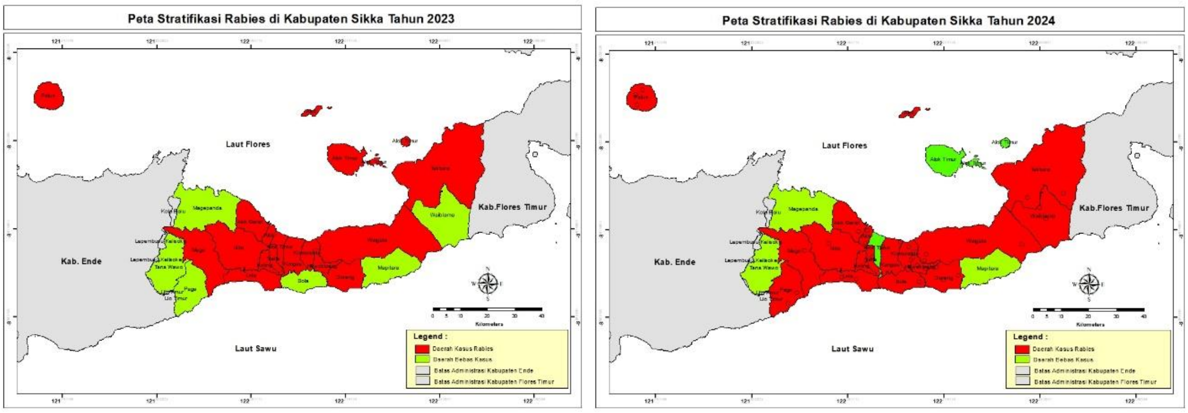

Figure 4. Rabies Stratification Map for 2023 and 2024