

## Mapping Zoonotic Disease Hotspots: The Power of GIS in Public Health

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### Introduction

Zoonotic diseases are a major public health concern in India. The country has a large livestock population, close and frequent human-animal contact, diverse agro-ecological zones and rapid socio-economic change. Diseases such as rabies, leptospirosis, brucellosis, tuberculosis, Japanese encephalitis and other emerging zoonoses continue to impose a heavy burden on both animal and human health, especially in rural and peri-urban areas.

Beyond India, zoonotic diseases remain a serious threat to global health and livelihoods. Increasing interaction at the human-animal-environment interface, along with climate change, urbanisation and the intensification of livestock production systems, has created complex patterns of disease transmission. These patterns vary from one location to another and change over time, which makes surveillance and control difficult using traditional methods.

Conventional surveillance systems, which rely mainly on aggregated tables and reports, often fail to capture where exactly diseases occur and how they spread over time. As a result, it can be hard for veterinary and public health authorities to identify true hotspots or to plan targeted interventions. In this context, Geographic Information Systems (GIS) have emerged as an essential tool for the spatial and spatio-temporal epidemiology of zoonotic diseases. By linking epidemiological data to place and time, GIS allows disease patterns to be visualised, analysed and

interpreted in ways that directly support evidence-based decision-making for prevention and control.

### What is GIS in zoonotic disease epidemiology?

A Geographic Information System (GIS) is a computer-based mapping and analysis tool that can capture, store, manage, analyse and display data that are linked to specific locations on the earth's surface. In zoonotic disease epidemiology, GIS is used to integrate information on disease occurrence in animals and humans with environmental, ecological and socio-economic factors.

These factors can include land use, rainfall, temperature, elevation, livestock density, vegetation, water bodies and human settlement patterns. When disease data (for example, outbreaks or case locations) are combined with such layers, maps can show not only where cases are occurring, but also what type of environment they occur in.

Unlike conventional approaches that only provide numbers at the district or state level, GIS highlights local spatial heterogeneity and how it changes over time. It also helps identify clusters of disease and high-risk areas. This spatial perspective provides valuable insights into transmission pathways, ecological drivers and risk factors associated with zoonotic diseases (Aranha et al., 2021).

For a field veterinarian or a district epidemiologist, this means that each village, farm or ward can be represented on a map, together with information such as livestock



population, vaccination status and past outbreaks. Such maps can then guide surveillance, vaccination and awareness campaigns.

## Applications of GIS in zoonotic disease surveillance and control

### 1. Disease surveillance and hotspot identification

One of the most common uses of GIS is to map the geographic distribution of zoonotic diseases and to detect spatial clusters of infection. By identifying high-risk areas, veterinary and public health authorities can prioritise surveillance, allocate limited resources more efficiently and implement targeted control measures.

For example, in rabies control, mapping dog-bite cases and dog vaccination coverage helps identify localities with low coverage, frequent bites or repeated human exposures. These maps make it easier to plan door-to-door dog vaccination campaigns, focus awareness activities on specific communities and monitor the impact of interventions over time (Kanankege et al., 2022).

### 2. Understanding spatial patterns of zoonotic diseases

Many zoonotic diseases have clear links to environmental and socio-ecological conditions. GIS allows disease data to be overlaid with relevant environmental layers so that spatial relationships can be examined and potential determinants of transmission can be identified.

Leptospirosis, brucellosis and Japanese encephalitis are good examples. Leptospirosis is often associated with heavy rainfall, waterlogging, flood-prone low-lying areas and poor sanitation. Brucellosis risk can be related to livestock density, management practices and the presence of informal slaughter points. Japanese encephalitis shows strong associations with irrigated paddy fields, pig rearing, water bodies and certain bird habitats. GIS-based approaches can effectively examine these spatial patterns and help highlight areas

where disease risk is particularly high (Aranha et al., 2021).

### 3. GIS-based risk mapping of vector-borne zoonoses

Vector-borne zoonotic diseases such as Japanese encephalitis, Rift Valley fever and others pose a major public health burden. GIS-based models that integrate climatic variables (rainfall, temperature), vegetation indices, vector habitat information and host distribution are commonly used to identify areas suitable for vector survival and disease amplification.

For Rift Valley fever, environmental suitability mapping using GIS has shown how rainfall, flooding, mosquito breeding sites and livestock movements combine to create high-risk zones. Such risk maps are useful for outbreak preparedness and for guiding risk-based surveillance, vaccination and movement control in animals before human cases occur (Tran et al., 2016).

### 4. Spatio-temporal analysis of zoonotic diseases

Most zoonotic diseases are dynamic: they show seasonal peaks, episodic outbreaks and long-term shifts driven by climate variability, animal movement, land-use change and human behaviour. GIS is not limited to static maps; it can also be used for spatio-temporal analysis, where disease patterns are studied across both space and time.

Spatio-temporal analysis may involve creating a series of maps by month or season, time-lapse animations of disease spread, or space-time cluster analyses. These tools help in early detection of emerging hotspots, understanding seasonal trends, distinguishing persistent endemic foci from short-lived outbreak zones and evaluating the impact of control measures such as vaccination campaigns or movement restrictions (Lawson, 2013).

While GIS is highly effective for spatial and spatio-temporal analyses, purely temporal analyses without any geographic reference are better handled with conventional time-series

methods. GIS is most valuable when time and place interact, as is the case for most zoonotic disease systems.

### GIS and the One Health approach

The One Health concept recognises that the health of humans, animals and ecosystems is interconnected. GIS naturally supports this approach by providing a shared platform where animal health, human health and environmental data can be brought together and visualised on the same map.

For example, human encephalitis cases, pig farm locations, migratory bird habitats and rice paddies can all be mapped and analysed together in a district. This enables joint risk assessment and planning between veterinarians, medical officers and environmental authorities. By enabling such spatial and spatio-temporal integration of multi-sectoral data, GIS strengthens the One Health framework promoted by the World Health Organisation (WHO) and the World Organisation for Animal Health (WOAH), and encourages coordinated surveillance, risk assessment and control of zoonotic diseases (WHO, 2017).

### Operational use of GIS in zoonotic disease control

In recent years, GIS has moved beyond academic research and is increasingly being used in day-to-day zoonotic disease control programmes. With GPS-enabled smartphones and tablets, field workers can collect geo-tagged data on outbreaks, vaccinations, animal movements and environmental conditions. These data can feed into real-time dashboards and interactive maps that decision-makers can access at the state or national level.

Such operational GIS applications are particularly useful for:

- Planning and monitoring mass dog vaccination campaigns for rabies.
- Tracking vector-borne zoonoses such as Japanese encephalitis and other mosquito-borne infections.

- Monitoring transboundary diseases along international borders or major livestock trade routes.

Open-source GIS software and freely available satellite data have made it possible even for resource-limited settings to begin using GIS for routine surveillance and planning.

### Challenges and limitations

Despite its many advantages, the wider adoption of GIS in zoonotic disease surveillance faces several challenges. Spatial data on animal populations, outbreaks and environmental factors may be incomplete, outdated or inconsistent in format. Technical expertise in GIS and spatial epidemiology can be limited, particularly at district and field levels. Hardware, software and internet connectivity may also be constraints in some settings.

In addition, issues of data quality, data sharing between sectors and institutions, and long-term maintenance of GIS systems need to be addressed. However, the growing availability of user-friendly, open-source tools and online training has begun to lower these barriers. Building capacity through training and integrating GIS into veterinary and public health education will be critical for sustainable use.

### Future perspectives

The future of GIS in zoonotic disease epidemiology lies in its integration with more advanced analytical tools and new data sources. Bayesian spatio-temporal modelling can quantify risk more precisely and account for uncertainty. Climate forecasts can be combined with GIS to anticipate disease risk linked to rainfall anomalies, heatwaves or flooding. Genomic surveillance data can be mapped to trace the movement and evolution of a particular pathogen strain across regions and countries.

Linking GIS with molecular epidemiology, remote sensing, and real-time data streams from the field will provide deeper insights into how zoonotic pathogens spread

and adapt. As environmental change and human-animal interactions continue to intensify, GIS-based spatial and spatio-temporal analyses will become indispensable for proactive zoonotic disease surveillance and control rather than simply reacting to outbreaks after they occur.

## Conclusion

GIS has become a cornerstone of modern zoonotic disease epidemiology. By enabling the spatial and spatio-temporal visualisation and analysis of disease patterns, it helps to strengthen surveillance systems, supports targeted interventions and enhances One Health collaboration. For veterinarians and public health professionals, the ability to understand and use simple disease maps can transform how outbreaks are detected, investigated and controlled.

In an era of emerging and re-emerging zoonoses, GIS is no longer an optional but an essential component of evidence-based zoonotic disease prevention and control.

## References

- Aranha, J., Abrantes, A. C., Gonçalves, R., Miranda, R., Serejo, J., & Vieira-Pinto, M. (2021). GIS as an epidemiological tool to monitor the spatial-temporal distribution of tuberculosis in large game in a high-risk area in Portugal. *Animals*, 11(8), 2374.
- Kanankege, K. S. T., Errecaborde, K. M., Wiratsudakul, A., Wongnak, P., Yoopatthanawong, C., Thanapongtharm, W., Alvarez, J., & Perez, A. (2022). Identifying high-risk areas for dog-mediated rabies using Bayesian spatial regression. *One Health* (Amsterdam, Netherlands), 15, 100411.
- Lawson, A. B. (2013). *Statistical methods in spatial epidemiology* (2nd ed.). Wiley.
- Tran, A., Trevennec, C., Lutwama, J., Sserugga, J., Gély, M., Pittiglio, C., et al. (2016). Development and assessment of a geographic knowledge-based model for

mapping suitable areas for Rift Valley fever transmission in Eastern Africa. *PLOS Neglected Tropical Diseases*, 10(9), e0004999.

World Health Organisation (WHO). (2017). *One Health*. WHO, Geneva.