Artificial Intelligence in Veterinary Public Health: Predicting Outbreaks Before They Happen

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Introduction

Veterinary public health is entering a new era; the same technologies that power online shopping recommendations, language translation and facial recognition are now being applied to animal health and zoonotic disease control. Under the broad term "artificial intelligence" (AI), tools such as machine learning and deep learning are being used to analyse complex datasets and build prediction models for animal disease outbreaks and zoonotic risks (Guo et al., 2023).

For veterinarians and epidemiologists, this shift is more than a buzzword. AI-based prediction models have the potential to improve early warning systems, guide vaccination campaigns, anticipate zoonotic spillover and support One Health decision-making. Instead of reacting to outbreaks only after they spread, AI can help us move towards proactive, risk-based prevention.

What do we mean by AI in veterinary epidemiology?

AI refers to computer systems that can perform tasks which normally require human intelligence, such as learning from data, recognising patterns or making decisions. In veterinary epidemiology, the most relevant branch is machine learning algorithms that learn patterns from historical data and then use those patterns to make predictions on new data (Muftic & Fejzić, 2024).

Conventional statistical methods are very useful, but they usually rely on relatively simple, often linear relationships and can find it difficult to cope with many variables and complex interactions. In contrast, AI and machine-learning approaches are built to work with:

- Large, multi-source datasets
- Non-linear relationships and interacting risk factors
- Imperfect, noisy and partially missing data that arise in real-world settings

For example, AI models can learn how combinations of rainfall, temperature, livestock density, market movements, biosecurity levels and previous outbreaks are linked with future disease occurrence, and then generate risk forecasts at farm, village or district level (Guo et al., 2023; Yoo et al., 2022).

Why prediction models matter for veterinary public health?

Prediction models are not about replacing veterinarians, but they are decision-support tools that can help answer practical questions such as:

- Which districts are at the highest risk for an outbreak next month?
- Where should vaccination or awareness campaigns be prioritised?
- How might climate anomalies like heavy rainfall or heatwaves affect disease patterns?
- Which farms or markets should be inspected first when resources are limited?

If used well, AI-driven models can help protect animal health, safeguard farmer livelihoods and reduce the risk of zoonotic transmission to humans (Guo et al., 2023).

Key applications of AI prediction models

1. Early warning of livestock disease outbreaks

A major application of AI in veterinary public health is its use in early warning systems. When machine-learning models are trained on past outbreak records together with information on weather, land use, animal movements and market activity, they can produce risk scores for diseases such as foot-and-mouth disease, haemorrhagic septicaemia, black quarter, brucellosis and avian influenza (Guo et al., 2023).

In a study from Korea, machine-learning models for Highly Pathogenic Avian Influenza (HPAI) combined data on weather, environment, wild-bird detections, on-farm biosecurity and livestock-related vehicle movements to estimate a daily infection probability for each poultry farm (Yoo et al., 2022). High-risk farms can then be flagged in advance, allowing veterinary services to target vaccination, adjust movements and strengthen biosecurity before outbreaks intensify.

2. Forecasting zoonotic and vector-borne diseases

Zoonotic diseases often depend on environmental drivers. AI models can combine meteorological data (rainfall, temperature, humidity), hydrological information (floods, waterlogging), land-use patterns and host population data to predict risk for diseases like leptospirosis, Japanese encephalitis or Rift Valley fever (Guo et al., 2023).

For example, a model may learn that a combination of heavy monsoon rains, certain soil types, paddy cultivation and high rodent or pig density is associated with increased risk in particular taluks or districts. Predictive maps can then help veterinary and medical teams coordinate One Health interventions such as rodent control, vaccination of livestock, public awareness on protective measures and pre-positioning of diagnostic kits.

3. Analysing movement networks and trade patterns

Livestock movement is a key driver of disease spread, especially for transboundary diseases such as foot-and-mouth disease, peste des petits ruminants, lumpy skin disease or highly pathogenic avian influenza. AI can analyse large volumes of movement and transport data, including vehicle tracking records and market transactions, to identify high-risk links and hubs in the network (Muftic & Fejzić, 2024; Yoo et al., 2022).

Prediction models built on such data can estimate the probability that a particular farm, village or market will be affected if an outbreak occurs elsewhere in the network. This supports more strategic movement control, targeted inspections and ring vaccination, while minimising unnecessary disruption to trade.

4. Improving surveillance efficiency

Resources for disease surveillance are always limited. Laboratory capacity, field staff and budgets cannot cover every sample or every village equally. AI can support risk-based sampling by ranking locations, flocks, herds or samples according to their predicted probability of being positive (Muftic & Fejzić, 2024).

For example, if a surveillance programme for brucellosis or bovine tuberculosis cannot test all animals, an AI model can help prioritise which herds or sub-populations to sample first based on past data, animal movements, farm size and other risk indicators. This can increase the chance of detecting infection early while keeping costs manageable.

5. Syndromic and event-based surveillance

AI is also being applied to less traditional data sources such as news reports, social media, online forums and field reports to detect unusual disease signals. Natural language processing (a branch of AI) can scan large volumes of text for key phrases related to animal illness, mortality events or food safety issues and classify relevant articles for epidemiologists (Roche & Trévennec, 2025).

Event-based surveillance systems for animal health, such as PADI-web in Europe, already use AI-driven text mining to filter and extract epidemiological events from online media, providing early warnings that complement official reports (Roche & Trévennec, 2025). Similar approaches could be adapted for veterinary surveillance networks elsewhere.

How do AI prediction models work?

Most AI-based prediction models in epidemiology follow a few basic steps:

1. **Data collection and cleaning**
   Historical disease data, climate records, livestock census figures, movement patterns and environmental layers are compiled, checked and cleaned.
2. **Feature selection and engineering**
   Relevant risk factors (for example, rainfall in the previous month, number of livestock markets, vaccination coverage, density of susceptible species) are identified and converted into a machine-readable form.
3. **Model training**
   A portion of the historical data is used to "train" the AI model, allowing it to learn how combinations of features are associated with disease occurrence or absence.
4. **Validation and testing**
   The model is tested on data it has not seen before to assess its accuracy, sensitivity and specificity. If the model performs poorly, it is adjusted or retrained (Villanueva-Miranda et al., 2025).
5. **Deployment and updating**
   After the model has been adequately trained and validated, it is put into routine use to produce up-to-date and forward-looking risk estimates. As fresh data are collected, the model can be periodically recalibrated and improved.

For veterinarians and public health officials who use these tools, all of this typically runs in the background and is accessed through simple, user-friendly platforms such as web dashboards or mobile applications.

Opportunities for India and One Health

India has several ingredients that make AI prediction models especially valuable:

- Large and diverse livestock populations across varied agro-climatic zones
- Multiple endemic and emerging zoonotic diseases
- Expanding digital infrastructure, including national disease reporting systems
- Growing availability of climate, remote sensing and socio-economic data

AI-based models tailored to local conditions can help state and national authorities strengthen early warning, rationalise vaccination and movement control, and design more effective, localised interventions. When combined with human health and environmental data, these tools can support genuine One Health planning, especially in hotspots where animal and human populations share water sources, agricultural land and peri-urban spaces (Guo et al., 2023).

Challenges and responsible use

While the potential of AI is exciting, it is important to recognise its limitations:

- **Data quality and availability**: AI models are only as good as the data fed into them. Under-reporting, inconsistent case definitions or missing location information can reduce reliability (Villanueva-Miranda et al., 2025).

- **Black box concerns**: Some AI models, especially deep learning, can be difficult to interpret. Veterinarians and policymakers need understandable outputs, not just risk scores (Muftic & Fejzić, 2024).
- **Technical capacity**: Developing, maintaining and updating AI systems requires collaboration between veterinarians, epidemiologists, data scientists and software developers.
- **Ethics and equity**: Use of AI should respect data privacy and ensure that benefits reach smallholder farmers and marginalised communities, not only well-resourced sectors (Guo et al., 2023).

Therefore, AI should be seen as a tool to support, not replace, veterinary expertise, field investigation and laboratory diagnosis. Ground-truthing predictions on the ground remains essential.

Future directions

Looking ahead, AI in veterinary public health and epidemiology is likely to move towards:

- **Integration with GIS and remote sensing**, producing dynamic spatio-temporal risk maps for multiple diseases and supporting fine-scale, farm-level risk prediction (Yoo et al., 2022).
- **Real-time early warning systems**, combining surveillance data, climate forecasts and movement information for rapid risk updates (Villanueva-Miranda et al., 2025).
- **Multi-disease and One Health models**, where animal, human and environmental data are analysed together to manage zoonotic threats (Guo et al., 2023).
- **User-friendly tools for field veterinarians**, such as mobile apps that display risk scores or suggest sampling priorities based on current conditions (Roche & Trévennec, 2025).

As these technologies mature, training veterinarians and public health professionals to understand and use AI outputs will be just as important as building the models themselves (Muftic & Fejzić, 2024).

Conclusion

Artificial intelligence is transforming many sectors, and veterinary public health is no exception. By learning from past data and recognising complex patterns, AI-based prediction models can strengthen early warning, support targeted interventions and improve the management of zoonotic and production diseases.

For veterinarians, epidemiologists and policymakers, embracing AI does not mean abandoning traditional skills. Instead, it offers powerful new tools to complement field knowledge, laboratory evidence and GIS-based mapping. Used wisely and responsibly, AI can help move veterinary public health from reactive crisis management to proactive, risk-based disease prevention, ultimately protecting animal health, human health and livelihoods.

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