Trends and future prediction of livestock diseases outbreaks by periodic regression analysis

P KRISHNAMOORTHY1, RASHMI KURLI2, S S PATIL3, PARIMAL ROY4 and K P SURESH5

ICAR-National Institute of Veterinary Epidemiology and Disease Informatics, one Bengaluru, Karnataka 560 064 India

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ABSTRACT

Livestock disease outbreaks become a burden to the animal husbandry farmers and cause great economic loss in India. Period regression analysis is used to find the periodic or cyclic character of livestock disease outbreaks in animals, as many other natural phenomena in environment is periodic or cyclic in nature. In present study, livestock disease outbreaks of anthrax (AX), black quarter (BQ), enterotoxaemia (ET), haemorrahgic septicemia (HS), bluetongue (BT), foot-and-mouth disease (FMD), peste des petits ruminants (PPR), sheep and goat pox (SGP), babesiosis (BA), fasciolosis (FA), theileriosis (TH) and trypanosomosis (TR) were analyzed using periodic regression to know the trend and future prediction of outbreaks. Time series data on disease outbreaks, month and year was collected from National Animal Disease Referral Expert System database for 2001–2016. The regression curves were prepared with baseline, observed outbreaks and upper bound curves for 12 livestock diseases. The analysis revealed decreasing trend for AX, BQ, ET, HS, FMD, PPR, SGP and a cyclical trend of peak occurrence for every 4–5 years was observed in BQ, PPR, SGP, FA and TR. However, TR showed increasing trend and BT, BA, FA, TH outbreaks were maintained at the same trend in the past and future also. Further, BQ in 2026, ET in 2020, HS in 2022, FMD in 2023, outbreak numbers may touch the zero point, if the preventive measures are continued for these diseases effectively. Thus, continuous and constant efforts are needed for prevention of livestock diseases outbreaks from all stakeholders, which will improve the economy of farmers in India.

Key words: Future prediction, Livestock diseases, Outbreaks, Periodic regression, Trend

Many biological, agricultural and livestock disease data are characterized by seasonal variations. Periodic phenomena is primarily close not only to biological data, but to non-biological data also. Periodic or cyclic phenomena are characteristic of many different types of data, which are synchronized with daily, lunar, or annual changes (Bliss 1970). The data following periodic or cyclical behaviour are often encountered, especially in agriculture (Cobanovic et al. 2006). Many kinds of agricultural data tend to fluctuate at regular time intervals and also showing characteristic of periodic nature (Little and Hills, 1978). The periodic or cyclic character of phenomena’s in nature is expressed in time and space. The earlier report indicated that the biological cycles may be divided into two, i.e. which depend on physical environment and those which do not depend on physical environment (Bliss, 1970). In the first category, the biological phenomenon is determined physiologically. In the second category, the cycles depend on many other potential risk factors, which can modify or change the biological phenomena. Meta-analysis of prevalence of subclinical, clinical and major mastitis pathogens in India was reported and identified in difference zones in India (Krishnamoorthy et al. 2017) and emphasized the importance of mastitis and major pathogens in dairy animals of India. In Tamil Nadu, the spatio-temporal epidemiological analysis identified the two zones and diseases which require preventive measures for effective control of livestock disease outbreaks (Krishnamoorthy et al. 2016).

Livestock disease outbreaks, affects the economy of the animal husbandry farmers in India. Analysis of previous disease outbreaks will help in future planning of the control and preventive measures effectively. An effective management for emerging and re-emerging diseases needs multidisciplinary activities like surveillance, rapid reporting, collection and transport of clinical materials for diagnosis of the etiological agents, strengthening of basic research, epidemiological modeling and prediction, forecasting model development, development of novel vaccine candidates and suitable adjuvant, etc. (Biswal et al. 2012). The livestock diseases may occur in seasonal and cyclical pattern in animals, if it is known by statistical analysis methods, it will help in effective utilization of available resources in planning the preventive measures.
No literature is available on the periodic regression analysis of livestock disease outbreaks in India. The trend pattern of livestock disease outbreaks will guide us whether the disease outbreaks are increasing or decreasing over a period of time and to ascertain the effectiveness of various vaccination programmes carried in India. Based on the past pattern of livestock disease outbreaks future outbreaks can be predicted by using prediction analysis. Hence, the present study was carried to analyse the livestock disease outbreaks occurred in India for the period 2001–2016 by using periodic regression analysis. This will help to know the trend pattern and future prediction of the diseases.

MATERIALS AND METHODS

The month wise data on 12 livestock disease outbreaks were collected from the National Animal Disease Referral Expert System (NADRES) database available at National Institute of Veterinary Epidemiology and Disease Informatics, Bengaluru, Karnataka which contains the livestock diseases outbreak data collected every month from all the states in India during 2001–2016. The data was segregated into bacterial, viral and parasitic diseases, each four in number, viz. anthrax [AX], black quarter [BQ], enterotoxaemia [ET], haemorrhagic septicemia [HS], bluetongue [BT], foot-and-mouth disease [FMD], peste des petits ruminants [PPR], sheep and goat pox [SGP], babesiosis [BA], fasciolosis [FA], theileriosis [TH] and trypanosomosis [TR]. The months were coded in numbers 1 to 12 and outbreak numbers were arranged in Microsoft excel for periodic regression analysis. In the analysis of the periodicity in the time series data, the important determinants were the length of the cycle or fundamental period, its amplitude or the range from the minimal to the maximal response and angular point in time during the periodic cycle when the response is maximal (Bliss, 1970). These parameters were easily estimated by using many statistical softwares.

A time series data or an outbreak \( Y_t (t=1, ..., N) \) observed at equal intervals of time was expressed as

\[
Y_t = \tilde{Y}_t + \epsilon_t,
\]

where \( \tilde{Y}_t \) is an unobserved fixed value at time t and \( \{\epsilon_t\} \) is a sequence of random errors identically and independently distributed with expectation 0 and variance \( \sigma^2 \). To determine variability of the livestock disease outbreaks data whether it has periodic components, the series was approximated by finite Fourier series of the form, if the number of data was even \( N=2n \),

\[
\tilde{Y}_t = A_0 + 2\sum_{m=1}^{n} \left( A_m \cos{2\pi m t} + B_m \sin{2\pi m t} \right) + \epsilon_t
\]

or if the number of data was odd: \( N=2n-1 \)

\[
\tilde{Y}_t = A_0 + 2\sum_{m=1}^{n-1} \left( A_m \cos{2\pi m t} + B_m \sin{2\pi m t} \right) + \epsilon_t
\]

Here \( \sqrt{A_0^2 + B_0^2} \) is the amplitude, and \( \phi_m = \arctg \left( B_m / A_m \right) \) is the phase of the i-th component. The \( \tilde{Y}_t \) function was in linear manner with combination of functions sin and cosinus along with frequencies, which was proportional to the frequencies \( f_1 = 1 \), so it became the linear multiple regression with regressors as sinus and cosinus functions.

\[
\frac{1}{N} \sum_{t=1}^{N} Y_t^2 = R_i^2 + 2\sum_{m=1}^{n} R_m^2 + R_0^2
\]

The contribution of i-th harmonical component to the mean of the total sum of squares of time series is equal to \( R_i^2 \), the periodic regression analysis was calculated as reported earlier by Éobanoviæ and Luèiæ (1992). By calculating the mean of total sum of squares, it was possible to single out harmonical components which describe the time series data as well. The periodic regression analysis was carried out by using R software version 3.2.2 CRAN (Comprehensive R Archive Network) and the statistical values for significance was based on P value and the regression curves were obtained.

RESULTS AND DISCUSSION

The detailed periodic regression analysis values of 12 livestock diseases for the period 2001–2016 are given in Table 1. Most of the livestock diseases showed the significance for intercept, X value, sinus and cosinus values and are given in the Table 1. The results of the present study concurred with the previous report for the periodic regression analysis (Éobanoviæ and Luèiæ, 1992). Four bacterial, viral and parasitic diseases were analyzed for trends of the disease and predicted the future disease outbreaks for the period from 2017–2026. The periodic regression analysis curve showed the baseline of the outbreaks, upper bound line which was 95% confidence interval from the baseline and the observed line indicated the actual outbreaks occurred during 2001–2016 in different months in a calendar year.

Bacterial diseases: The bacterial diseases included for the study were AX, BQ, ET and HS. The trend pattern and prediction curves of AX and BQ are given in Fig. 1. The AX outbreaks showed 55 outbreaks during 2001 and reduced to 20 outbreaks during 2016. The trend analysis revealed that the AX outbreaks are decreasing slowly, but outbreaks were reported continuously every year in India. This might be due to the effective use of AX spore vaccine in the large and small ruminants. The observed outbreaks curve revealed that many a times it has crossed the upper bound curve and indicated the epidemic nature of this disease in livestock over the period. Further, the preventive vaccination against AX has to be taken seriously in livestock, since AX outbreaks will continue to occur beyond 2026 also as per the prediction curve. BQ periodic analysis curve revealed a fast decreasing trend in the outbreak numbers from 100 outbreaks in 2001 to 12 outbreaks in 2016, and the outbreaks, i.e. baseline will touch the zero point during 2026 based on the prediction analysis. This might be due to the effective vaccination followed against this disease in different parts of the country and the current strategies should be continued for controlling the BQ in livestock. The baseline and upper bound curve for AX and BQ revealed a cyclical pattern of increasing outbreaks for
Table 1. Periodic regression analysis values of livestock disease outbreaks in India for 2001–2016

| Disease                | Parameter | Estimate | Standard Deviation | t value | P value | R value | R² | Adjusted R² |
|------------------------|-----------|----------|--------------------|---------|---------|---------|----|-------------|
| **Bacterial diseases** |           |          |                    |         |         |         |    |             |
| Anthrax                | Intercept | 9.849    | 0.701              | 14.05   | <0.001**| 0.40499 | 0.16402 | 0.14784     |
|                        | x         | -0.026   | 0.006              | -4.357  | <0.001**|         |    |             |
|                        | c1        | -1.295   | 0.411              | -3.153  | 0.002** |         |    |             |
|                        | sl        | 0.392    | 0.419              | 0.936   | 0.351** |         |    |             |
| Black Quarter          | Intercept | 39.211   | 2.031              | 19.307  | <0.001**| 0.53862 | 0.29012 | 0.27638     |
|                        | x         | -0.121   | 0.018              | -6.862  | <0.001**|         |    |             |
|                        | c1        | 3.293    | 1.228              | 2.682   | 0.008** |         |    |             |
|                        | sl        | 0.669    | 1.352              | 0.495   | 0.621** |         |    |             |
| Enterotoxaemia         | Intercept | 21.72    | 1.404              | 15.472  | <0.001**| 0.55304 | 0.30586 | 0.29242     |
|                        | x         | -0.099   | 0.012              | -8.178  | <0.001**|         |    |             |
|                        | c1        | -2.384   | 0.919              | -2.595  | 0.01**  |         |    |             |
|                        | sl        | -1.087   | 0.953              | -1.141  | 0.256   |         |    |             |
| Haemorrhagic Septicemia| Intercept | 58.643   | 3.269              | 17.94   | <0.001**| 0.56827 | 0.32294 | 0.30984     |
|                        | x         | -0.237   | 0.028              | -8.428  | <0.001**|         |    |             |
|                        | c1        | 0.958    | 2.009              | 0.477   | 0.634** |         |    |             |
|                        | sl        | -0.578   | 2.101              | -0.275  | 0.784** |         |    |             |
| **Viral diseases**     |           |          |                    |         |         |         |    |             |
| Bluetongue             | Intercept | 4.133    | 0.891              | 4.637   | <0.001**| 0.17655 | 0.03117 | 0.01242     |
|                        | x         | -0.015   | 0.008              | -1.91   | 0.058** |         |    |             |
|                        | c1        | -0.919   | 0.605              | -1.519  | 0.131** |         |    |             |
|                        | sl        | 0.205    | 0.62               | 0.33    | 0.742** |         |    |             |
| Foot-and-mouth disease | Intercept | 100.715  | 6.983              | 14.422  | <0.001**| 0.45890 | 0.21059 | 0.19531     |
|                        | x         | -0.386   | 0.061              | -6.382  | <0.001**|         |    |             |
|                        | c1        | -2.359   | 4.429              | -0.533  | 0.595   |         |    |             |
|                        | sl        | -0.844   | 4.625              | -0.183  | 0.855** |         |    |             |
| Peste des petits ruminants | Intercept | 29.925  | 1.985              | 15.074  | <0.001**| 0.38974 | 0.1519  | 0.13538     |
|                        | x         | -0.084   | 0.017              | -4.812  | <0.001**|         |    |             |
|                        | c1        | -4.429   | 1.321              | -3.354  | 0.001** |         |    |             |
|                        | sl        | 1.472    | 1.301              | 1.132   | 0.26**  |         |    |             |
| Sheep and Goat Pox     | Intercept | 2.066    | 0.715              | 2.889   | 0.004** | 0.56427 | 0.3184  | 0.3052      |
|                        | x         | 0.045    | 0.007              | 6.829   | <0.001**|         |    |             |
|                        | c1        | 3.337    | 0.52               | 6.424   | <0.001**|         |    |             |
|                        | sl        | 1.442    | 0.527              | 2.739   | 0.007** |         |    |             |
| **Parasitic diseases** |           |          |                    |         |         |         |    |             |
| Babesiosis             | Intercept | 9.081    | 1.356              | 6.695   | <0.001**| 0.43747 | 0.19138 | 0.17573     |
|                        | x         | -0.023   | 0.013              | -1.719  | 0.088** |         |    |             |
|                        | c1        | 0.153    | 0.896              | 0.171   | 0.865** |         |    |             |
|                        | sl        | 5.282    | 1.016              | 5.197   | <0.001**|         |    |             |
| Fasciolosis            | Intercept | 12.089   | 1.897              | 6.372   | <0.001**| 0.53005 | 0.28095 | 0.26703     |
|                        | x         | -0.023   | 0.018              | -1.288  | 0.2**   |         |    |             |
|                        | c1        | -2.437   | 1.263              | -1.93   | 0.055** |         |    |             |
|                        | sl        | 9.711    | 1.343              | 7.23    | <0.001**|         |    |             |
| Theileriosis            | Intercept | 6.977    | 0.845              | 8.262   | <0.001**| 0.29764 | 0.08859 | 0.07095     |
|                        | x         | -0.015   | 0.008              | -1.94   | 0.054** |         |    |             |
|                        | c1        | 0.245    | 0.547              | 0.448   | 0.655** |         |    |             |
|                        | sl        | 1.803    | 0.608              | 2.966   | 0.003** |         |    |             |
| Trypanosomosis         | Intercept | 30.396   | 7.067              | 4.301   | <0.001**| 0.47998 | 0.23038 | 0.20188     |
|                        | x         | -0.16    | 0.049              | -3.264  | 0.002** |         |    |             |
|                        | c1        | -8.242   | 1.82               | -4.528  | <0.001**|         |    |             |
|                        | sl        | 2.536    | 1.18               | 2.149   | 0.035   |         |    |             |

nsNonsignificant; *Significant at 95% level (P<0.05); **Significant at 99% level (P<0.01).
Fig. 1. Periodic regression analysis of bacterial disease outbreaks–anthrax (A) and black quarter (B).

Fig. 2. Periodic regression analysis of bacterial disease outbreaks–enterotoxaemia (A) and haemorrhagic septicemia (B).
Fig. 3. Periodic regression analysis of viral disease outbreaks—bluetongue (A) and foot-and-mouth disease (B).

Fig. 4. Periodic regression analysis of viral disease outbreaks—pesti des petits ruminants (A) and sheep and goat pox (B).
Fig. 5. Periodic regression analysis of parasitic disease outbreaks—babesiosis (A) and fasciolosis (B).

Fig. 6. Periodic regression analysis of parasitic disease outbreaks—theileriosis (A) and trypanosomosis (B).
The periodic regression curves of bacterial, viral and parasitic diseases will help in knowing the trends, prediction of future outbreaks and assist in planning the preventive measures, allocation of scarce resources effectively. The BQ, HS and FMD, the major diseases of livestock will reach zero point, if the constant and continued efforts are undertaken for these diseases. The livestock diseases which need to be taken on priority for prevention were known by this analysis and helps the policy maker for making informed decisions. This is the first report of periodic regression analysis of livestock disease outbreaks in India to the best of our knowledge.

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