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Seasonality Analysis of the Incidences of Major Livestock and Poultry Diseases in Meghalaya, India

Anjoo Yumnam[1]*, R.K. Sanjukta[1], N.U. Singh[1], A. Roy[2] and Pampi Paul[1]

[1]ICAR Research Complex for NEH Region, Umiam, Meghalaya, INDIA
[2]Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur, Bihar, INDIA

Corresponding author: A Yumnam; E-mail: anjooyumnam102@gmail.com

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ABSTRACT

Livestock diseases incur huge cost on the farmers in the form of decreased productivity, mortality, control treatment and other shadow price such as the value of the offspring that could have been born. The understanding of the seasonal pattern and variation in disease incidence will show implications towards planning efficient disease control programme and vaccination. The present study analysed the pattern of incidence of major livestock diseases in Meghalaya over the years (2010-2015), the characteristics of its incidence within a year and discuss the effects of trade and environment on the seasonality of these diseases. Lorentz curves and corresponding Gini Coefficients showed that the distribution of all the eight diseases within a year were non-uniform, highest variation being observed in Caprine FMD. Near to equal distributions throughout the year with non-distinct peak were observed for Swine Fever, Bovine BQ and Bovine HS. The monthly seasonality of FMD incidences in bovine, swine and caprine, Swine Fever and Ranikhet Disease were highest in monsoon and least in winter and the seasonality was explained better by the seasonality of the import of these livestock than the environmental factors. While Fowl pox also had the same order of seasonality, the environmental factors seems to be indirectly linked to it, probably through high mosquito activities in monsoon, rather than the volume of import of poultry. Other physical or cultural factors such as seasonal human activities also explain the seasonal incidences of these diseases which needs further investigation.

HIGHLIGHTS

- Infectious diseases are known to show seasonality in its incidence.
- Seasonality in the incidence of six viral and two bacterial infectious diseases in livestock and poultry were assessed.
- The study examined and discussed the effects of trade and environment on the seasonality of the diseases.

Keywords: Gini Coefficient, Livestock Diseases, Lorentz curve, Meghalaya, Seasonality

Infectious diseases are known to show seasonality in its incidence due to the nature of the persistence of the causal agents according to weather conditions. Seasonality means a surge in the disease incidence in a particular season or period within a year. The recognition of seasonality of disease occurrence is longstanding, dating at least to the time of Hippocrates (~ 380 BC) (Fares, 2013). A seasonal pattern in the occurrence of a disease, say a temporal clustering, a cyclical variation, or a long-term trend, suggests the presence of environmental factors in its aetiology (Hayes *et al.,* 2022). Apart from the seasonal components, there are multiple causes of livestock diseases. Socio-economic and cultural factors such as farming system practice, choice of fodder or crop cultivation, concentration of livestock population, dynamics of vectors and host, import of the pathogen, etc causes the surge of livestock disease incidence by affecting the environment (Gale *et al*., 2009). The micro as well as the macro environments created by socio-economic and

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cultural factors for the flourish and persistence of the diseases is affected by climatic variables such as rainfall, temperature and relative humidity (Gale *et al*., 2009). So, an attempt has been made to observe and analyse the trend in livestock diseases, the characteristics of seasonality for each disease and the mechanisms underlying the seasonality with special regard to environmental and trade factors.

Livestock rearing is an important income earning avenue for Meghalaya which has only about 12% net sown area. According to National Sample Survey report on Income, Expenditure, Productive Assets and Indebtedness of Agricultural Households in India, small and marginal farmers dominate the livestock farming in Meghalaya earning an average net income of ₹ 1148 per month per household mostly from milk and live animal sale (Government of India, 2013). Livestock diseases incur huge cost on the farmers in the form of decreased productivity, mortality, control treatment and other shadow price such as the value of the offspring that could have been born. The small, marginal and landless farmers bear the brunt when they have been subject to sudden and surprise livestock disease outbreak. The veterinary hospitals and aid centres in the state is not sufficient to reach the difficult terrain and large area of the state (Yumnam and Deka, 2022). So, the logical and efficient approach is to focus on prevention of prevalent infectious diseases. Heath care management practices such as vaccination and deworming ensure proper heath of animals that promotes their productivity (Yadav *et al.,* 2021). The understanding of the seasonal pattern and variation in disease incidence will show implications towards planning efficient disease control programme and vaccination. This will avoid untoward culling of livestock and huge cost on treatment and overall low productivity. So, the present study will analyse the pattern of incidence of major livestock diseases in Meghalaya over the years, the characteristics of its incidence within a year and discuss the mechanisms for the seasonality. The multi-disease analysis will enhance our understanding of the mechanisms which cause seasonality in disease incidence and may indicate a probable future trend.

MATERIALS AND METHODS

The study was conducted in the state of Meghalaya, which is one of the eight states lying in the north eastern part of India between latitude 24°58' to 26°07'N and longitude 89°48' to 92°51'E. The state is a typical hilly state interspersed with small valleys and gorges with elevation ranging from 150 m to 1950 m above sea level. The total annual rainfall ranges from 2000 mm to 12000 mm with an average monthly rainfall of about 217.89 mm. There is much variation in temperature across the state with the western part being relatively warmer (12°C - 33°C) and central part cooler (2°C - 24°C). It shares state boundary with Assam state to the north and east and international boundary with Bangladesh to the west and south.

The monthly incidence of livestock diseases as recorded by the Directorate of A. H. and Veterinary, Government of Meghalaya was used for the study. The disease record for six important viral and two bacterial diseases in four different categories of livestock have been used for the analysis (Table 1). In order to analyse the seasonality, temporal clusters and long term cycle of the disease incidences, an average dataset was created for the state covering five years (2010 – 2015) for livestock diseases and three years (2010-2013) for poultry diseases. Table 2 presents the total incidence of livestock diseases in the state over the study period.

Table 1: Prevalent livestock diseases in Meghalaya

Pathogen	Disease	Transmission
Viral	Bovine FMD (Foot and Mouth Disease) Swine FMD Caprine FMD	Airborne, infected animals, meat, milk, fodder and inanimate objects
	Swine fever	Infected herd, human, meat
	Ranikhet Disease (RD)	Infected live birds and animals
	Fowl Pox	Infected scabs, mosquitoes, inanimate objects
Bacterial	Bovine BQ (Black Quarter)	Infected fodder and grass, soil borne
	Bovine HS (*Haemorrhagic septicaemia*)	Infected animals, damp soil and water

The data has been subject to decomposition analysis to extract the trend, seasonal and random component. The monthly time series have been described using an additive model, and the "decompose()" function in R was used, which estimates the trend, seasonal, and irregular components of a time series that can be described using an additive model. The monthly seasonality index was manually calculated using "Ratio to moving average method", which is the most widely used method of measuring seasonal variations (Gupta, 2011). The disease patterns were assessed using Gini-coefficients, for which the proportions of disease incidence per month were calculated by dividing the average monthly incidence by average annual incidence. These monthly proportions were used to construct Lorentz curves for the diseases. Lorentz curves are mostly used for assessing the distribution of income over the population and in the present study will be used to assess the distribution of disease incidence across the year. To construct the Lorentz curve, the months are ranked by the number of incidences from lowest to highest, then the cumulative percentage of 'cases' are plotted against the cumulative percentage of a year. A straight 45° diagonal line indicates equal distribution of the disease incidence across the year. A concave curve indicates unequal distribution where the 'concavity' of the curve represents the concentration of cases through the year. If some diseases cluster around a month, the curve would almost coincide with X-axis and jump up at the right uppermost part of the plot (Lal, 2012).

Table 2: Total disease incidence in livestock and poultry in Meghalaya (2010-2015)

Sl No.	Disease	Outbreak	Attack	Death
1	Bovine FMD	678	14169	17
2	Swine FMD	53	584	0
3	Caprine FMD	72	706	0
4	Swine fever	338	3004	701
5	Ranikhet Disease (RD)	204	10334	3404
6	Fowl Pox	179	11831	773
7	Bovine BQ	112	1680	12
8	Bovine HS	97	1375	18

So, the knowledge of the area between the Lorentz curve and the straight 45° diagonal line gives an important implication about the degree of inequality in the distribution. The Gini Coefficient provides an index value which shows the degree of inequality or temporal clustering. It is calculated as twice the area between the Lorentz curve and the straight 45° diagonal line, or as the ratio of the aforementioned area to the area under the diagonal line. Its value lies between 0 and 1, with larger values indicating greater concentration while a smaller one indicates greater uniformity. The methodology used by Lal (2012) for construction of Lorentz Curves and calculation of Gini Coefficients have been closely followed.

The effect of trade on the seasonality of livestock and poultry diseases was estimated by examining the seasonal imports of different categories of livestock into the state. The seasonality in rainfall and temperature variables was examined to estimate the effect of environmental factors on seasonality of livestock and poultry diseases.

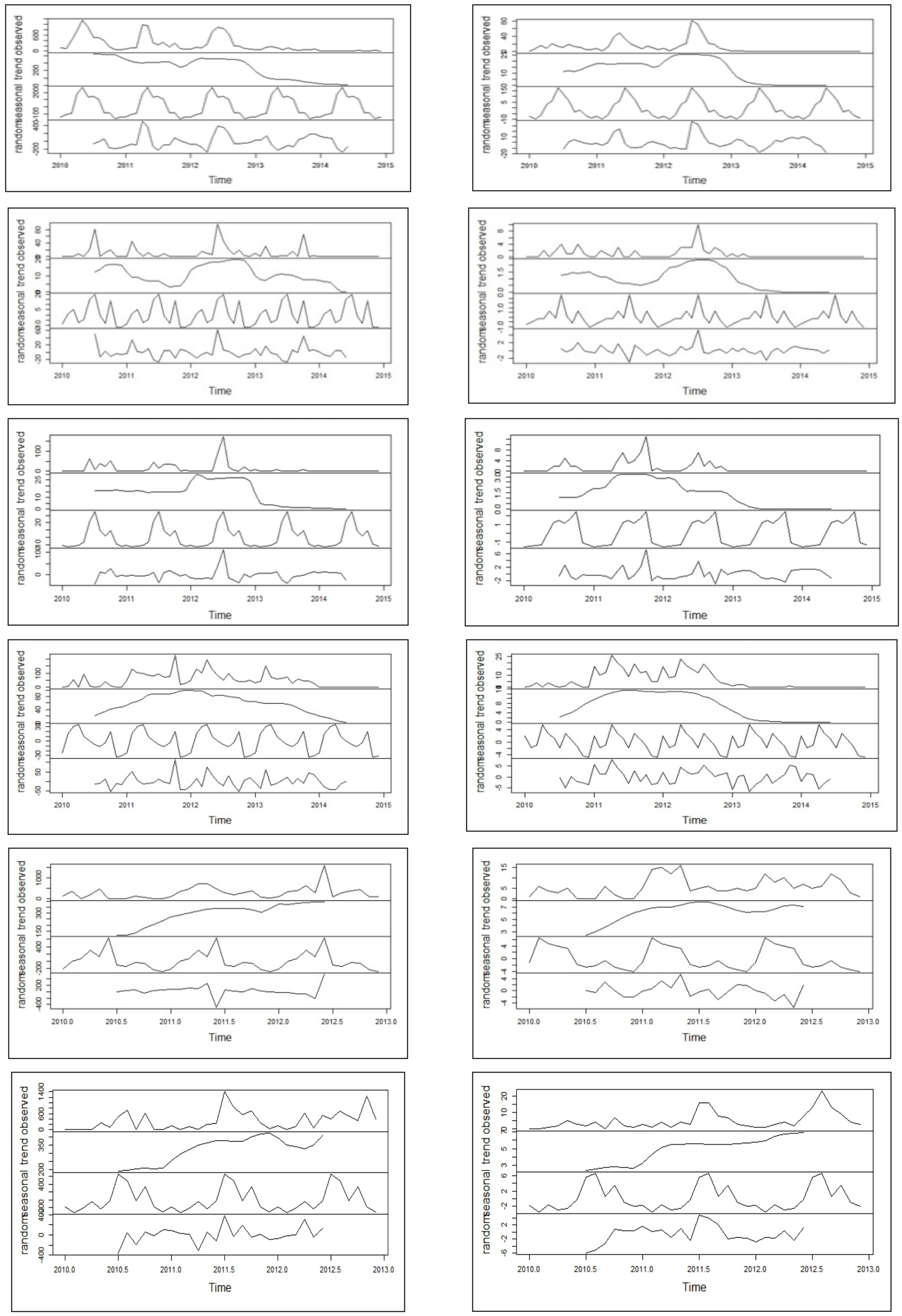
RESULTS AND DISCUSSION

Decomposition Analysis

The district wise data of disease incidence available in three categories viz., disease attack and disease outbreak has been aggregated for the whole state for the decomposition analysis. Due to the administrative arrangement of the state which resulted in formation of four new districts in 2013, a district level decomposition analysis has been ruled out. The results are presented for eight prevalent livestock diseases viz., Bovine FMD, Swine FMD, Caprine FMD, Swine Fever (SF), Ranikhet Disease (RD), Fowl Pox, Bovine BQ and Bovine HS. Cattle FMD has the highest number of incidences followed by Swine fever, Ranikhet Disease and Fowl Pox.

The monthly incidence of the aforementioned diseases from 2010 to 2015 has been decomposed into trend, seasonality and random components and is presented in Fig. 1. The observed data for Bovine FMD showed three peaks in disease attacks and two peaks in disease outbreak. The trend line shows that disease attacks and outbreaks have been consistently decreasing over the years. The observed monthly incidence of Swine FMD Attack has many peak points whereas only one peak is clearly observed in Swine FMD outbreak. The trend shows a roughly cyclical trend with peaks and troughs. The observed incidences of Caprine FMD showed that the disease attack has been consistently low apart from a single peak of disease incidence. Swine Fever is found to be prevalent in the state, however both attack and outbreak showed decreasing trends during the period. Two very important diseases of birds, particularly poultry viz., Ranikhet Disease and Fowl Pox have shown

Disease Attack Trend **Disease outbreak trend**



Bovine FMD

Swine FMD

Caprine FMD

Swine Fever

Ranikhet

Fowl Pox

Bovine BQ

Bovine HS

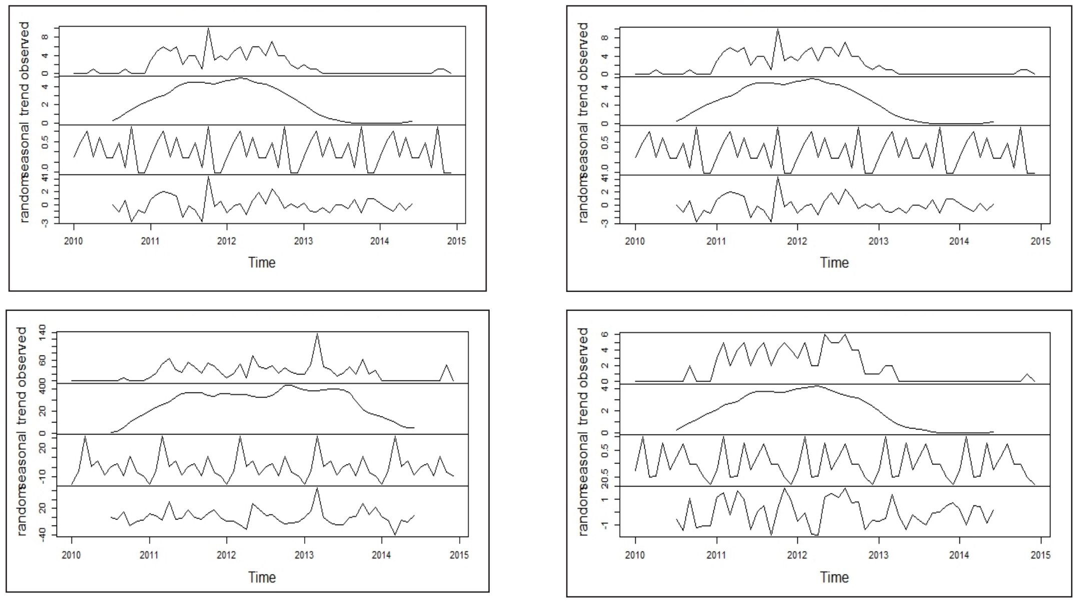


Fig. 1: Components of trends in major livestock diseases of Meghalaya

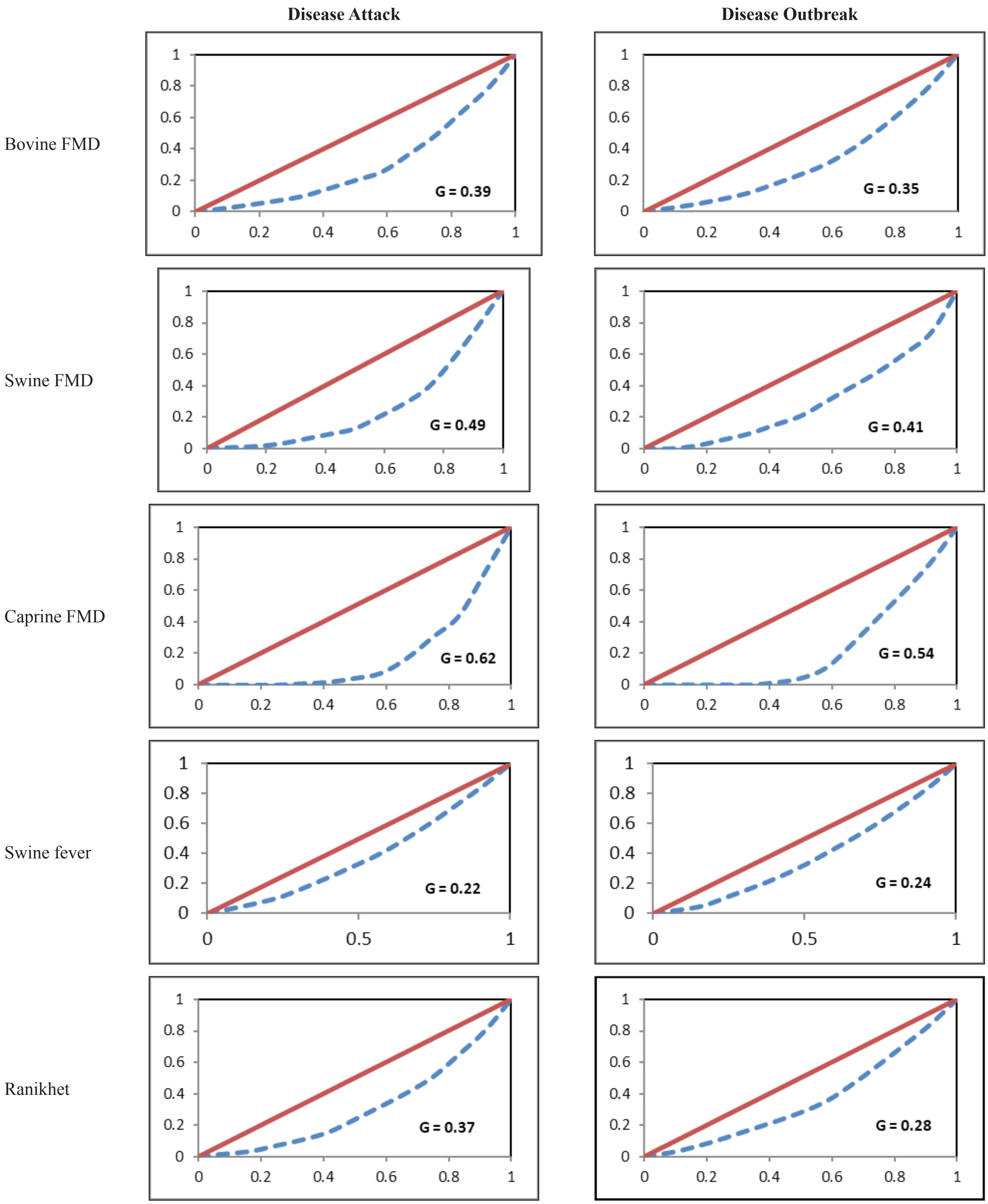
increasing trend components during the period. The surge in the disease outbreak of both these diseases is found to be more in the last two years of the study period. The bacterial diseases BQ and HS in Bovine were found to be of regular prevalence during the period however with a decreasing trend. The seasonal components of all the diseases attack as well as outbreak indicate explicitly the non-uniform distribution over the months in a year. However, to compare the distribution among different diseases, Lorentz Curve and Gini Coefficients were applied.

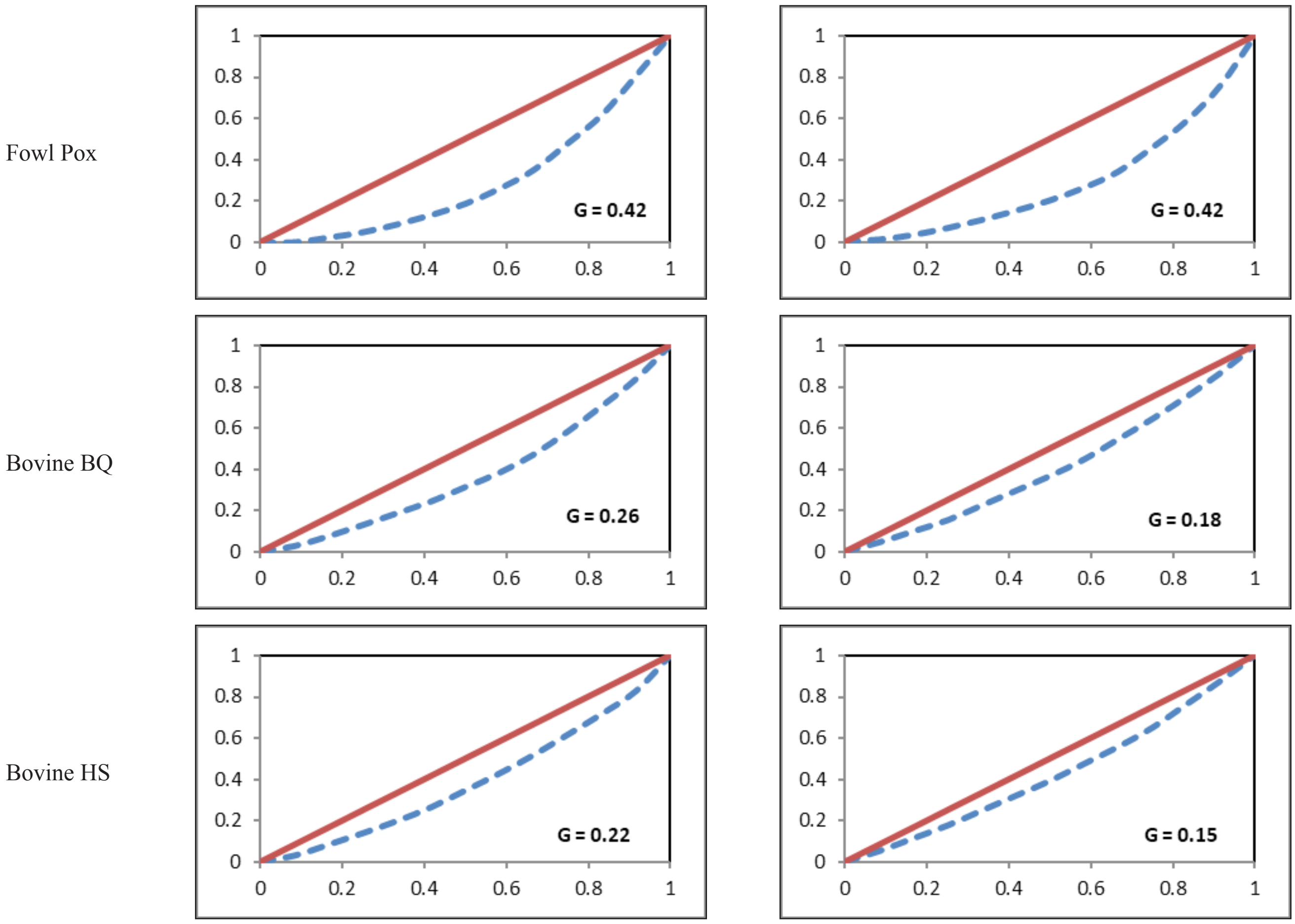
Lorentz Curve and Gini Coefficient

The Lorentz curves for the eight different livestock and poultry diseases attack and outbreak are presented in Fig. 2. The horizontal axis represents cumulative proportion of year and vertical axis represents cumulative proportion of disease incidence. The solid black line represents equal incidence through the year, and the dotted line represents the cumulative incidence. The Lorentz Curves and corresponding Gini Coefficients of all the diseases were found to show non-uniform distribution of disease attack as well as disease outbreak through the year. Flatter Lorentz Curves and lower Gini Coefficients were observed for Swine Fever, Bovine BQ and Bovine HS, indicating near to equal distribution throughout the year with non-distinct peak. The Lorentz Curves for Caprine FMD for both attack and outbreak showed a highly skewed shape with highest Gini Coefficients among the diseases. Bovine FMD, Swine FMD, Ranikhet Disease and Fowl pox had high temporal variation through the year indicated by the broadness of the Lorentz curves, though distinct peaks were not observed in Swine FMD and Ranikhet Disease. It was also observed that the Lorentz Curves were flatter and corresponding Gini Coefficients closer to zero in case of disease outbreak than in disease attack in all the diseases except in Swine Fever.

Monthly seasonality index

Fig. 3 shows the overall monthly seasonality indices over the study period. The seasons in Meghalaya are categorised into three – Summer (March – June), Monsoon (July – October) and Winter (November – December). The overall monthly seasonality for Bovine FMD attack indicates a bi-modal peak, during summer (Mar-Jun) and early rainy season (Jul-Oct). Bovine FMD outbreak has single peak in rainy season. The peak for outbreak during rainy season indicates association with weather parameter like the relative humidity. Swine FMD does not show a well-defined seasonality, peaks are observed in all the three


Disease Attack
Disease Outbreak
Bovine FMD
G = 0.39
G = 0.35
Swine FMD
G = 0.49
G = 0.41
Caprine FMD
G = 0.62
G = 0.54
Swine fever
G = 0.22
G = 0.24
Ranikhet
G = 0.37
G = 0.28



Note: Horizontal axis: cumulative proportion of year; Vertical axis: cumulative proportion of disease incidence; G : Gini Coefficient.

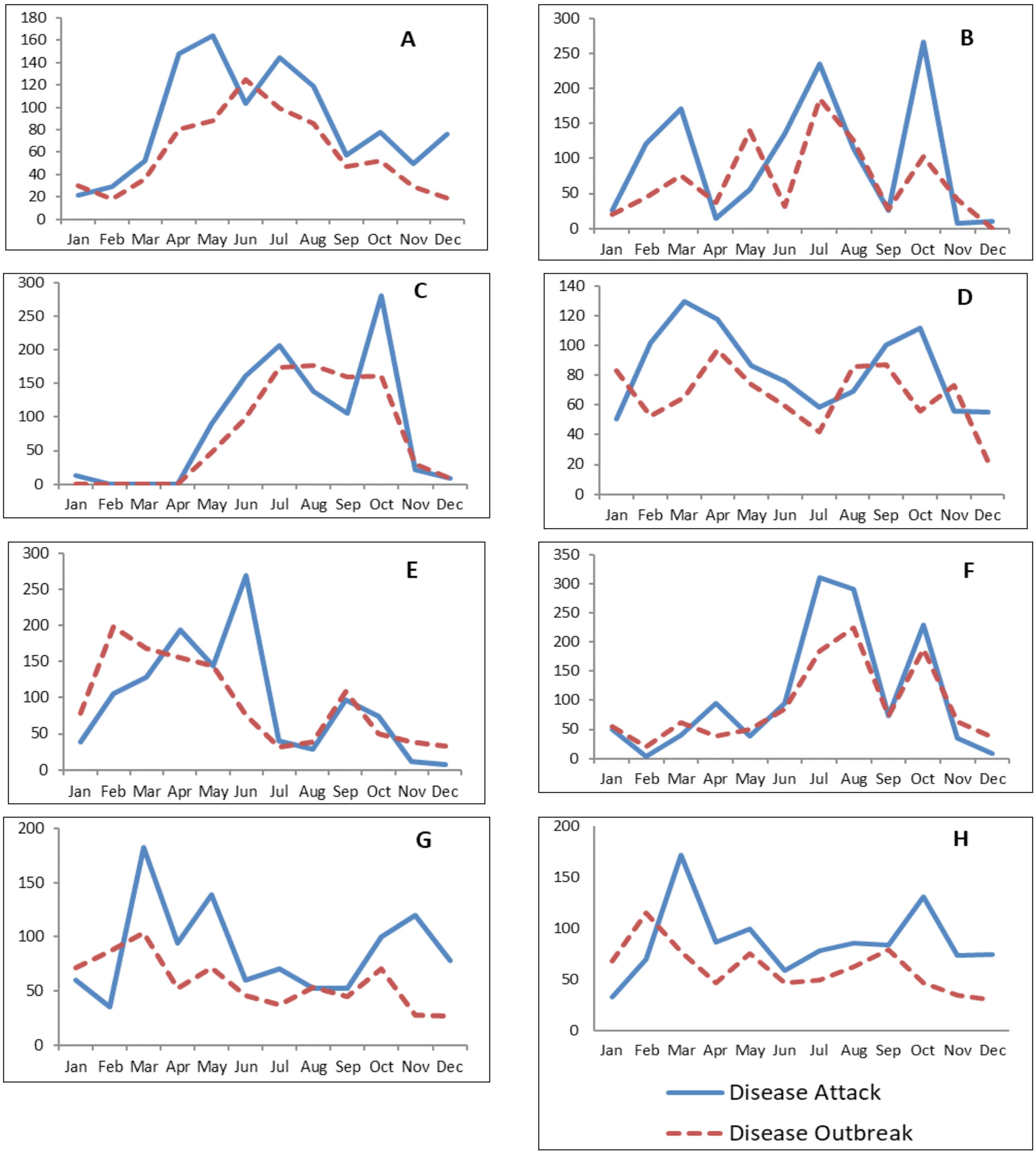
Fig. 2: Lorentz Curves and corresponding Gini Coefficients of the livestock diseases

seasons. This disease may well be considered to occur throughout the year, with highest incidence of outbreak during the onset of rainy season. Caprine FMD attack has highest peak in October and another in June, whereas the outbreak has no unique peak point but an extended peak covering few months during the monsoon season. Swine flu has clear bimodal peak in its disease attack during early summer (March) and late monsoon (October). Swine flu outbreak showed three peaks during all the seasons.

Ranikhet Disease attack has the highest peak during summer and another smaller peak in monsoon, while the outbreak peaked during late winter (February). Both the attack and outbreak of Fowl Pox peaked twice during monsoon season. Bovine BQ and Bovine HS showed similar seasonality with attack peaking during early summer and late monsoon. The disease outbreak in both Bovine BQ and Bovine HS showed no definite seasonality as there were peaks in all the three seasons.

Mechanisms underlying seasonality

The mechanisms for the seasonality in these diseases may be ascribed to seasonal phenomena prevalent in the region including weather and seasonal human activities such as trade. However, the seasonal coincidence of such phenomena and the diseases is not sufficient to deduce a causal relationship between them. Nevertheless, the apparent and probable causes for seasonality of diseases will be discussed regarding two selected phenomena viz., environment and livestock trade.



Note: A: Bovine FMD; B: Swine FMD; C: Caprine FMD; D: Swine Flu; E: Ranikhet Disease; F: Fowl Pox; G: Bovine BQ; H: Bovine HS

Fig. 3: Monthly seasonality indices of common livestock diseases of Meghalaya (%)

Environmental effects on disease incidence

The seasonal physical environment such as temperature, rainfall and relative humidity have been known to affect the abundance, survival and virulence of the pathogens and also increase the susceptibility of hosts and vectors. The characteristics of two climatic variables viz., temperature and rainfall have been presented in Fig. 4 as the seasonality indices derived from a five year data of the state. The seasonality analysis of average monthly temperature reveals that the hottest month in Meghalaya is August which is 3.06°C higher than the average annual temperature of 21.6°C and coldest in the month of January which is 6.43°C lower than the average. The seasonality analysis of average monthly rainfall of Meghalaya shows that July is the rainiest month receiving 355.56 mm more rainfall than the average monthly rainfall of 217.89 mm. The driest month in Meghalaya is December receiving

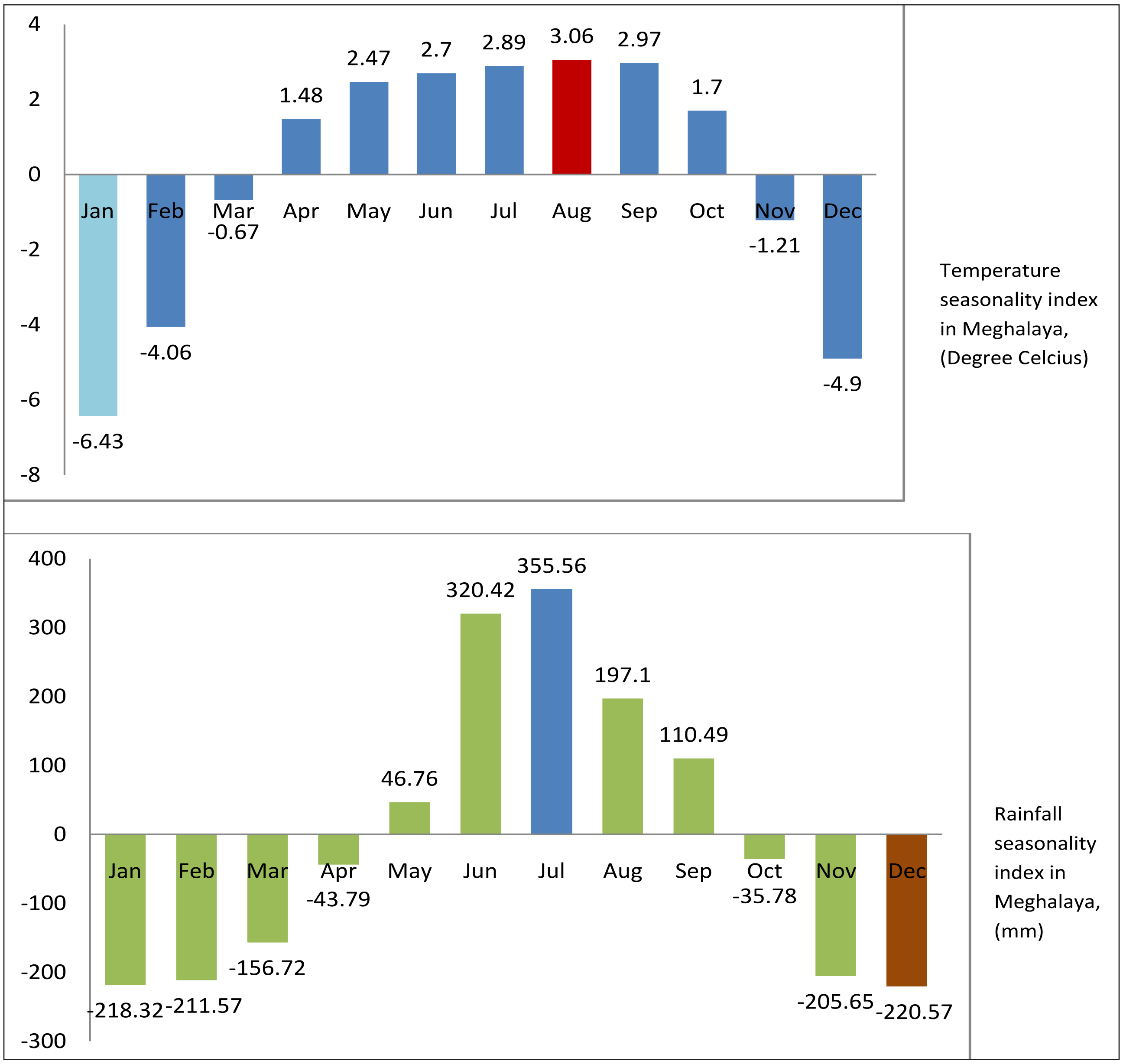


Fig. 4: Monthly Seasonality Indices of temperature and rainfall in Meghalaya

220.57 mm lesser rainfall than the average monthly rainfall. Considering the characteristic of these two climatic variables, the mechanisms of seasonality in the eight livestock diseases will be discussed.

The major route of transmission of FMD virus is airborne spread of aerosol spread and via fomites (Bhattacharya, 2005; Paton *et al.,* 2018; Auty *et al.,* 2019). Dry weather and dry winds with moderate RH (Relative Humidity) and low temperature favour the transmission of the virus through air. The seasonality analysis of Bovine FMD, Pig FMD and Caprine FMD revealed that the incidences were relatively higher during the rainy season. Contradicting results have been found in the states of West Bengal, Uttar Pradesh and Overall India where the incidence of FMD outbreak were highest during winter than in summer or monsoon (Bhattacharya, 2005; Verma, 2008; Subramaniam, 2022) This may be due to the average low temperature in Meghalaya with the maximum temperature going only up to 24°C (21+3.06°C). The swine fever virus is a highly resistant one known to survive high temperatures upto 50°C and freezing temperatures. In normal farm conditions, the virus survives for at least 4 weeks during winter (Blome *et al.,* 2017). Swine fever peaked during low temperature (early summer) and low rainfall (late monsoon) period of the year in Meghalaya. The diseases in fowl generally peaked during monsoon season, with the exception of Ranikhet Disease outbreak which peaked during late winter (February). This is in accordance with the findings by Sharma *et al.* (2015) in Jammu, Borah *et al*. (2017) in Assam. The Ranikhet Disease Virus has maximum viability in the range of the ambient temperatures 11°C - 36°C and has more survival chance below 20°C. This in combination with dry weather may have facilitated in transmission of RD virus and caused the surge in its outbreak during winter (February). Mosquitoes are important carriers for Fowl Pox virus which explains the surge of the disease incidence during monsoon. Black Quarter and HS of Bovine are two bacterial diseases which occur throughout the year but the highest was found in early summer and pre monsoon (Feb – Mar). In Tamil Nadu, the disease incidences of BQ and HS were highest during summer and monsoon respectively (Sivakumar, 2012). Since there doesn't seem to be explicit relationship between environmental factors and the incidences of BQ and HS in Meghalaya, the causes may be attributable to other seasonal, cultural and farming practices or import of meat and live animals from outside the state. For instance, Black Quarter outbreaks are associated with excavation of soil, which can expose and activate latent spores (Sultana, 2008).

Trade effects on incidence of livestock diseases

Direct physical contact or close proximity with infected animals is one of the major causes of livestock disease outbreak. The lack of strict legislation and controls in inter-state movement of livestock pose a big risk in the spread of infectious diseases in livestock. Attempt was made to understand the seasonal pattern of import of the different livestock category. For this purpose, the data on the number of livestock slaughtered as available in the report on integrated *Sample survey for estimation of production milk, egg and meat* by Directorate of Animal Husbandry & Veterinary, Government of Meghalaya was used. The total number of livestock imported into the state for slaughter was highest in cattle (120321 nos.) which constitute 50% of the total livestock imported. It was followed by poultry (95104 nos.), pig (23384 nos.) and sheep/goat (6360 nos.) during 2015-16. The average proportions of the import in different seasons for six years (2010-2016) were analysed (Table 3). The percentages are expressed for each category of livestock in a year. The amount of imports were highest during monsoon (Jun – Oct) followed by summer (Mar – May) and winter (Nov – Feb) for Cattle and pig. For Sheep/Goat and poultry, the highest imports were recorded during winter followed by summer and monsoon.

Table 3: Average percent import of livestock animals in different season (%)

Livestock category	Summer	Monsoon	Winter
Cattle	33.10	35.34	31.56
Pig	33.37	34.39	32.25
Sheep/Goat	32.26	32.14	35.60
Poultry	33.38	27.95	38.66

The seasonality of FMD in cattle, pig and caprine followed the order monsoon>summer>winter which is same as that of the import in each livestock category. Trade has been known as the vehicle for spread of FMD. There is a generally positive relation between the volume of live animal imported from riskier regions and the probability of a disease outbreak (Shanafelt, 2015). Since the data for Meghalaya does not specify the region from where the imported livestock originate, it is impossible to establish such kind of relationship. But nonetheless, there is apparent link between the pattern of animal movement through trade and the prevalence of FMD outbreak. Swine fever is another livestock disease where transboundary spread is quite likely, either through meat or live animal trade. Classical Swine Fever spread from the Netherlands to Italy and Spain through the shipment of infected piglets in 1997 (Beltrand-Alcrudo, 2019) is one of the most prominent evidence of transboundary spread of livestock disease. The seasonality of swine fever followed the order summer>monsoon>winter which is not exactly in order of the seasonal volume of import of pig in Meghalaya. Ranikhet Disease or Newcastle Disease is one of the highly infectious avian diseases which are likely to spread through trade (Cobb, 2011). In Meghalaya, the seasonal pattern of Ranikhet disease outbreak (winter>summer>monsoon) and the volume of trade in poultry showed an apparent connection. Fowl pox is less likely to be spread through trade as the virus enters through cuts and abrasions or through mosquito bites. The seasonal pattern of Fowl Pox outbreak and volume of trade in Meghalaya does not show any apparent relationship. Bovine Black Quarter is a high mortality disease but the link between its outbreak and volume of trade is not explicit. In case of Bovine HS too, the observation of the seasonal pattern in trade volume and that of the disease occurrence did not show any evidence of a relationship.

CONCLUSION

Bovine FMD, Swine Fever, Bovine BQ and Bovine HS attacks and outbreaks have been consistently decreasing over the years. Swine FMD showed a roughly cyclical trend with peaks and troughs. Caprine FMD was the least prevalent and also showed a decreasing trend. The poultry diseases viz., Ranikhet disease and Fowl pox have however shown increasing trend components during the period. Lorentz curves and corresponding Gini Coefficients showed that the distribution of all the eight diseases within a year were non-uniform, highest variation being observed in Caprine FMD. Near to equal distributions throughout the year with non-distinct peak were observed for Swine Fever, Bovine BQ and Bovine HS. The monthly seasonality analysis revealed that FMD incidences in bovine, swine and caprine, Swine Fever and Ranikhet Disease were highest in monsoon and least in winter. The seasonality in these diseases was explained better by the seasonality of the import of these livestock than the environmental factors. While Fowl pox also had the same order of seasonality, the environmental factors seems to be indirectly linked to it, probably through high mosquito activities in monsoon, rather than the volume of import of poultry. The seasonality of Bovine BQ incidences showed highest outbreak during summer and least in winter while that of Bovine HS showed highest outbreak in winter and least in summer. Neither the pattern of environmental factors nor import of cattle had apparent relationship with the seasonality of these two diseases. Other physical or cultural factors such as excavation of soil, farming practices or any other seasonal human activities might explain the seasonal incidences of these two diseases which needs further investigation.

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