Bluetongue In Brazil: A Spatiotemporal Analysis (2001-2023)

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Abstract:

Background: *Bluetongue is a non-contagious viral disease caused by the bluetongue virus (Orbivirus), affecting domestic and wild ruminants, particularly sheep. Transmission occurs primarily through vectors of the genus Culicoides, with distribution influenced by environmental and climatic factors. In Brazil, disease outbreaks are sporadic; however, bluetongue is classified as a notifiable disease due to its economic and epidemiological significance and its potential to be mistaken for foot-and-mouth disease.*

Materials and Methods: *This study analyzed the temporal and spatial distribution of bluetongue outbreaks in Brazil from 2001 to 2023, investigating possible associations with climatic variables such as temperature, precipitation, and wind speed. Data were obtained from the Zoosanitary Information System Panel (MAPA-SIZ) and organized into spreadsheets for statistical analysis. Pearson's correlation test and spatial lag regression were applied using the Jamovi and GeoDa software, respectively.*

Results: *A total of 51 bluetongue virus infection outbreaks were recorded, comprising 482 cases predominantly concentrated in southern Brazil. Sheep were the most affected species (73% of cases), followed by wildlife (20%), goats (6%), and cattle (2%). The analysis revealed a significant inverse correlation between the annual mean temperature and the occurrence of cases and outbreaks ($r^2=0.306$ and $r^2=0.379$ respectively), indicating higher disease prevalence in states with lower temperatures. No statistically significant correlations were observed between disease occurrence and either precipitation or average wind speed. However, international studies suggest that wind can facilitate the long-distance dispersion of Culicoides, while mild temperatures extend vector survival.*

Conclusion: *The results suggest that temperature is a determining factor in the spatial and temporal distribution of bluetongue in Brazil, whereas precipitation and wind speed have limited influence. The sporadic occurrence of the disease underscores the importance of continuous surveillance to prevent outbreaks and improve disease control. Strategies that account for vector population dynamics and climatic conditions could enhance the effectiveness of monitoring and control measures.*

Key Word: *Culicoides, surveillance, outbreaks, virus*

I. Introduction

Bluetongue is a non-contagious viral disease caused by the bluetongue virus (BTV), which belongs to the family *Reoviridae*, genus *Orbivirus* [1]. It is subject to mandatory and immediate notification to the Official Veterinary Service [2]. Due to its significant economic impact on global livestock production, Bluetongue is considered a disease of multi-species importance by the World Organisation for Animal Health (WOAH) [3] [4].

The disease has been documented since the 17th century [5]. Currently, 28 serotypes of BTV are recognized, each with varying capacities to cause disease. In sheep, for instance, morbidity can reach 100%, while mortality ranges from 2% to 70% [1] [3]. BTV has been identified in several South American countries, including Brazil, Argentina, Colombia, Guyana, Suriname, Ecuador, Peru, and Chile [6] [7] [8]. In Brazil, serotypes BTV-1, 3, 4, 9, 10, 12, 13, 14, 17, 18, 19, 20, 22, and 24 have been detected; however, serological studies conducted since the 1980s suggest the circulation of other serotypes in the country [1].

Transmission of BTV occurs primarily through hematophagous vectors of the genus *Culicoides*, affecting both domestic and wild ruminants. Sheep are particularly susceptible, but cattle, goats, buffalo, antelopes, deer, elk, and camels can also be affected [3] [9] [3].

Since 1998, significant changes in the epidemiology of arboviruses transmitted by *Culicoides* have

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been observed, including the introduction of exotic viruses in temperate regions, an increase in global incidence, and greater viral diversity in tropical areas [10].

The present study aims to investigate possible associations between the prevalence of the disease and climatic variables, such as temperature, precipitation, and wind speed, as well as to assess the existence of seasonal patterns in the affected Federative Units.

II. Material And Methods

Study Location: Brazil

Study Duration: June to December 2024.

Data Coverage Period: 2001 to 2023

Study Design: Retrospective observational study

Inclusion Criteria:
1. Outbreaks and cases reported with laboratory diagnosis recorded in the SIZ
2. Animals of either sex

Exclusion Criteria:
1. Outbreaks without an indicated month of disease onset were excluded from the temporal analysis

Statistical Analysis
Climatic and Seasonality Analysis
Information on Bluetongue occurrence was obtained from the Panel of the National Zoosanitary Information System (SIZ) of the Ministry of Agriculture and Livestock (MAPA) [11]. Climatic variables were obtained from the official websites [12] of Brazil. To assess the temporal relationship between variables in the affected Federative Units, Pearson's correlation test was applied. This test evaluates the strength and direction of the linear relationship between variables, producing a correlation coefficient (r) ranging from -1 to 1. Values close to 1 indicate a strong positive correlation, while values close to -1 indicate a strong negative correlation. Values near 0 suggest little to no correlation. The climatic variables analyzed were: monthly average temperature in °C; monthly average precipitation in mm; monthly average wind speed in m/s.

Spatial Lag Regression Model
To identify patterns of spatial dependence, a spatial lag regression model was applied. This statistical model considers that the values of a variable in one location may be influenced by the values of the same variable in neighboring locations. Initially, spatial dependence was investigated by constructing a Queen contiguity spatial weight matrix, which considers neighboring states as those sharing borders or vertices. A spatial lag regression model (SAR-lag) was fitted using the maximum likelihood method. This model incorporates spatial dependence directly into the dependent variable through a spatial lag term (Rho). The elimination of residual autocorrelation was assessed using the Global Moran's I test applied to the model residuals.

The analysis model used, a Spatial Autoregressive Lag Model (SAR-lag), was compared to a conventional linear regression model to evaluate its effectiveness in capturing spatial patterns related to the distribution of Bluetongue outbreaks in Brazil. While the traditional linear model assumes spatial independence of the data, the SAR-lag model accounts for spatial autocorrelation, enabling more accurate analysis in situations where geographical proximity influences the results.

The analyses were conducted using R software (version 4.2.2), supported by the *spatialreg*, *spdep*, and *sf* packages, as well as GeoDa software (version 1.22). Data were organized and structured in Microsoft Excel 2013 spreadsheets to facilitate statistical analysis.

III. Result

Between 2001 and 2023, 51 outbreaks of Bluetongue virus (BTV) infection were reported in Brazil, resulting in 482 diagnosed cases. The distribution of cases and outbreaks by region is presented in **Table no 1.** The spatial distribution of Bluetongue in Brazil highlights a concentration of outbreaks in the South and Southeast regions, with a higher prevalence in the states of Paraná, Rio Grande do Sul, and Rio de Janeiro, which together account for 93% of the cases. The North region reported two outbreaks, and only six Federative Units were affected by the disease.

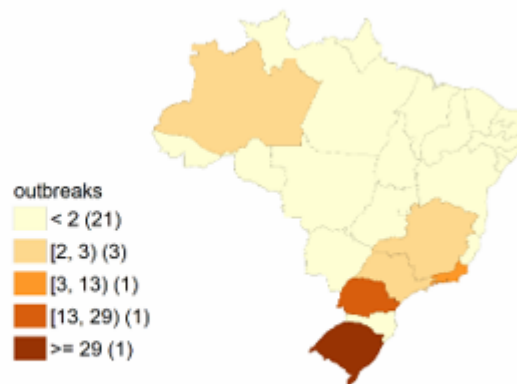| Table no 1: Distribution of Bluetongue cases and outbreaks in Brazil, by federal unit (UF), from 2001 to 2023.		
UF	Outbreaks	Cases
AM	2	17
MG	2	11
SP	2	4
PR	13	100
RS	29	234
RJ	3	116
Brazil	51	482

outbreaks
- < 2 (21)
- [2, 3) (3)
- [3, 13) (1)
- [13, 29) (1)
- >= 29 (1)

Figure 1 shows the temporal distribution of Bluetongue cases and outbreaks in Brazil. Peaks of infection were observed in the years 2002, 2013, 2014, and 2015, characterizing outbreak periods. Following these episodes, the reduction in the occurrence of outbreaks may be associated with the implementation of effective control measures, such as monitoring and sanitary surveillance actions, or with environmental conditions less favorable for the maintenance and spread of the virus, particularly due to reduced activity of vectors from the *Culicoides* genus.
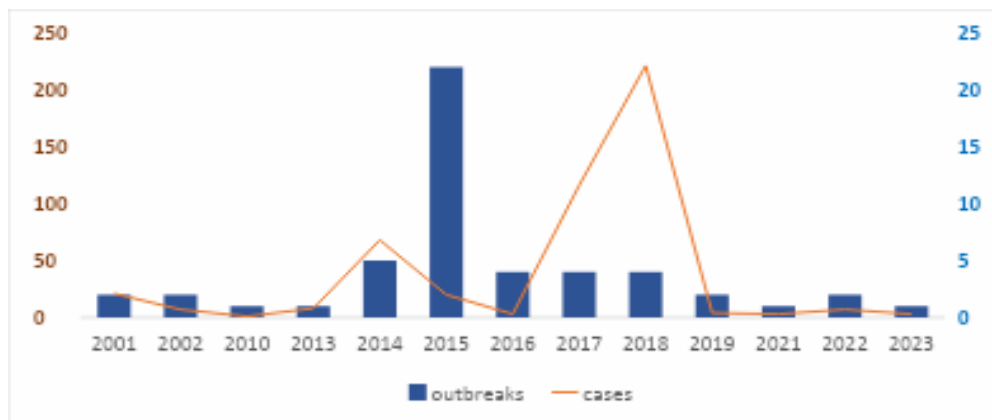

Figure no 1: Temporal distribution of bluetongue outbreaks and cases in Brazil (2001–2023)

The affected species were predominantly sheep, accounting for 73% of the cases, followed by wildlife at 20%, goats at 6%, and cattle at 2%, as shown in **Figure no 2.**
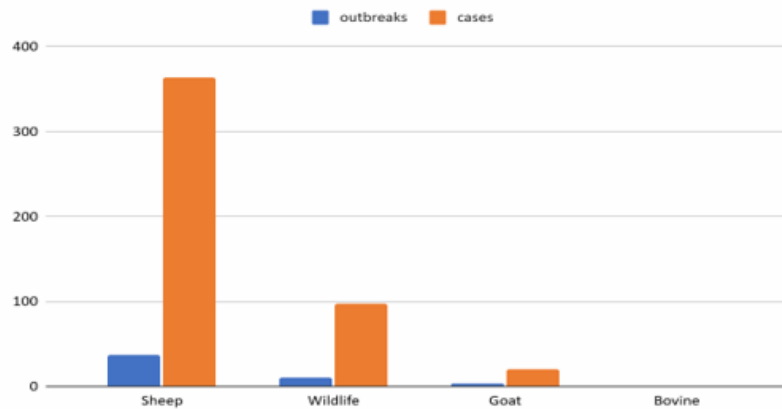
Figure no 2: Distribution of the number of Bluetongue cases and outbreaks by species in Brazil, from 2001 to 2023

The analysis revealed an annual average of 2.31 outbreaks, while the average number of cases per outbreak was approximately 14. However, the ratio between cases and outbreaks varied widely, ranging from a minimum of 1 case per outbreak to a maximum of 101 cases per outbreak. This variation highlights heterogeneous scenarios: while some outbreaks involved few cases, others concentrated a high number of infections, indicating significant differences in disease dynamics across regions and periods. In certain years, the number of cases was significantly higher than the number of recorded outbreaks. This suggests that, although infection points did not spread widely between properties, there was more intense virus transmission among animals within specific properties.

These patterns indicate that Bluetongue occurrence in Brazil seems to be influenced by random fluctuations or external factors, such as climatic or ecological conditions. The temporal trends reflect periods of outbreaks followed by control measures, but without evidence of clear periodicity. This underscores the importance of continuous monitoring and control strategies.

Seasonality and Climate

Figure 3 shows the variation in monthly average temperatures in Brazil during the study period, highlighting higher temperatures at the beginning and end of the year, while intermediate months show lower average temperatures. States with reported Bluetongue cases exhibit average temperatures below the national average, reflecting the impact of local climatic conditions on disease occurrence.

The highest incidence of Bluetongue virus infection was observed in southern Brazil, a region with a temperate climate and milder temperatures. However, a significant peak in cases and outbreaks was recorded in February and March, coinciding with the rainy and warmer season. Following this period, there was a gradual decrease in incidence, reaching its lowest levels between October and December.

These data suggest that the mild temperatures prevailing in the South, combined with increased humidity during warmer periods, may create optimal conditions for the proliferation of *Culicoides* vectors. These patterns point to a potential seasonal behavior of the disease. However, the correlation test did not reveal a significant association between monthly average temperature and disease occurrence in the affected states. This can be partially explained by the reduced number of occurrences in the second half of the year, despite the gradual increase in average temperature starting in July.
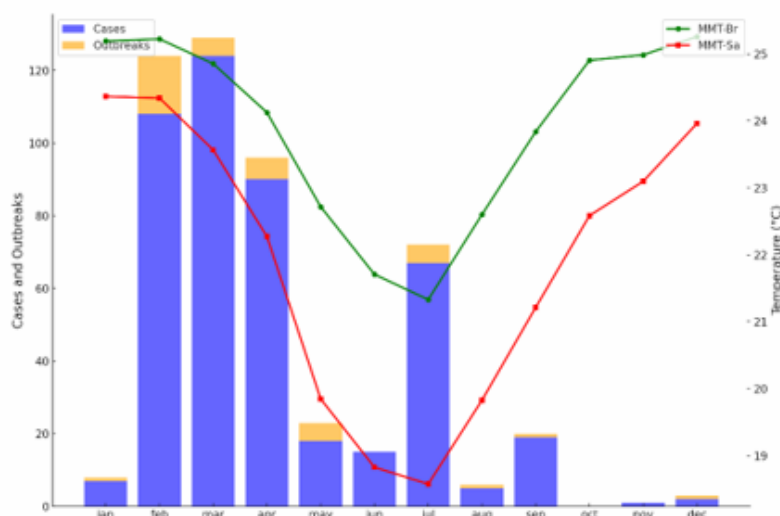
Figure no. 3: Monthly variation in Bluetongue cases and outbreaks, and temperature in Brazil (MMT-Br) and affected UFs (MMT-Sa) from 2001 to 2023.

The Pearson correlation analysis revealed a correlation coefficient of 0.458, indicating a moderate positive correlation between Bluetongue cases and average monthly precipitation. However, the p-value of 0.135 indicates that this correlation is not statistically significant at the 5% level. This suggests that there is insufficient evidence to establish a consistent relationship between Bluetongue outbreaks and average monthly precipitation in the Federative Units where the disease was reported.

The monthly variation in average wind speed in Brazil compared to Bluetongue cases and outbreaks is shown in **Figure no. 4**. It is observed that in the affected states, the average wind speed is below the national average throughout all months, and cases and outbreaks do not follow the same seasonal pattern. However, during the first half of the year, months with weaker winds appear to coincide with a higher number of cases and outbreaks.
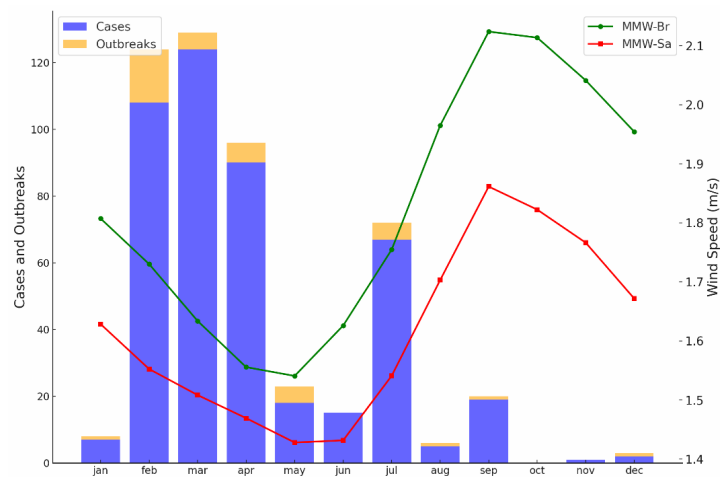

Figure no. 4: **Monthly variation in bluetongue cases and outbreaks, and wind speed in Brazil (MMW-Br) and affected UFs (MMW-Sa) from 2001 to 2023.**

The Pearson correlation test revealed a coefficient of -0.439, suggesting a moderate negative correlation. However, the p-value of 0.154 indicates that this correlation is not statistically significant at the 5% level. These results suggest insufficient evidence to confirm a significant seasonal correlation between Bluetongue outbreaks and the average wind speed in the affected regions.

Spatial Regression Model SAR-Lag

To investigate spatial dependence in the distribution of Bluetongue outbreaks, a spatial lag regression model (SAR-lag) was fitted. This model assessed the relationship between outbreaks and climatic variables,

including mean annual temperature (MAT), mean annual precipitation (MAP), and mean annual wind speed (MAW). The results of the model are shown in **Table no. 2**.

Table no 2: Results of the Spatial Lag Model and Residual Autocorrelation Tests				
Variable	Coefficients	Std. Error	z value	Pr(>|z|)
mat	-2.0129	0.356	-5.6416	<0.001
map	0.0036	0.002	2.0797	0.0375
maw	1.7059	0.897	1.9023	0.0571
Rho: -0.59481, LR test value: 8.6023, p-value: 0.0033574				
Log likelihood: -74.63062 for lag model				
ML residual variance (sigma squared): 13.383, (sigma: 3.6582)				
AIC: 161.26, (AIC for lm: 167.86)				
LM test for residual autocorrelation				
test value: 0.62001, p-value: 0.43104				

Interpretation of Results

The results from the Spatial Lag Model indicate the following:

Annual Mean Temperature (MAT): The MAT variable showed a significant negative regression coefficient (-2.01; $p < 0.001$), indicating that an increase of one unit in MAT is associated with an average reduction of 2.01 outbreaks, holding other variables constant, as illustrated in **Figure no. 5a**

Annual Mean Precipitation (MAP): The MAP variable had a significant positive coefficient (0.0037; $p = 0.038$), suggesting that municipalities with higher precipitation levels experience a slight increase in bluetongue outbreaks, as illustrated in **Figure no 5b.**

Annual Mean Wind Speed (MAW): The MAW variable presented a positive coefficient (1.711; $p = 0.057$), indicating a marginally significant positive association between stronger winds and an increase in outbreaks, as illustrated in **Figure no 5c.**

Model Fit: The log-likelihood was -74.63, and the Akaike Information Criterion (AIC) was 161.26, indicating that the SAR-lag spatial regression model provides a better fit compared to the traditional linear regression model (AIC = 167.86).The residual variance was estimated at 13.38 (sigma = 3.66).

Spatial Pattern: The negative spatial dependence (Rho < 0) is consistent with a heterogeneous dispersal pattern of the disease, where areas with a high number of outbreaks tend to be surrounded by areas with fewer cases. This result may be related to more effective control measures in neighboring areas of outbreaks.

Model Adequacy: The SAR-lag model performed well, eliminating the residual autocorrelation observed in the traditional linear model. This reinforces the importance of accounting for spatial effects in the analysis of geographic animal health data.
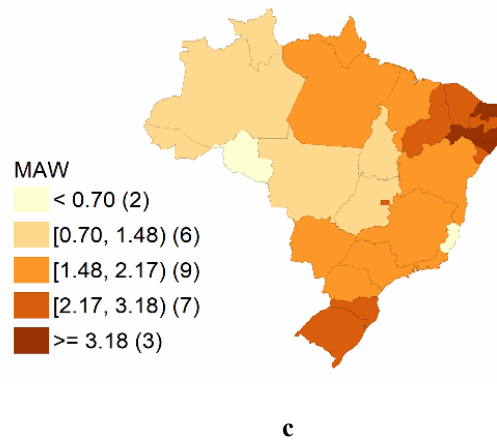

a

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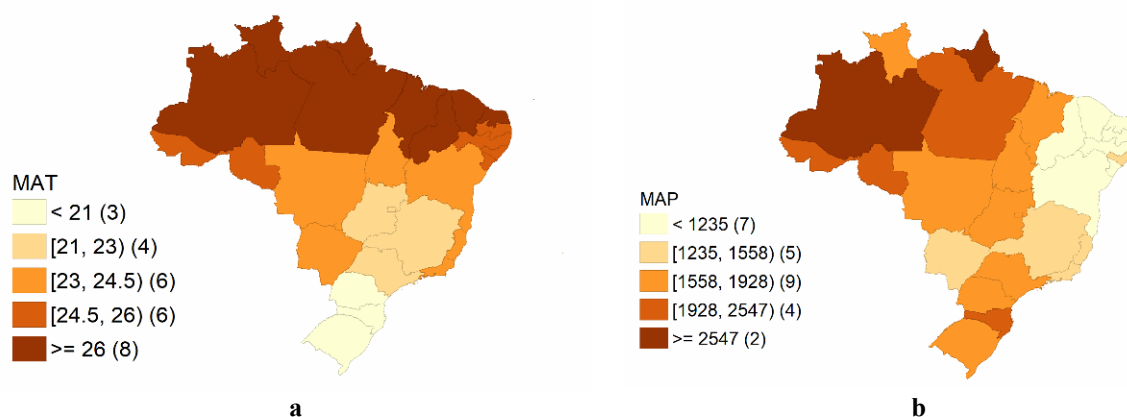
Figure no 5: Choropleth maps of (a) Mean monthly temperature, (b) mean monthly precipitation, (c) mean wind speed across the federative units of Brazil (2001–2023). These maps illustrate the spatial distribution of key climatic variables over the study period. The patterns observed in these maps should be compared with the data presented in Table no 1 to better understand the potential influence of these variables on the spatial distribution of Bluetongue outbreaks.

IV. Discussion

The higher prevalence of bluetongue in sheep, coupled with its lower prevalence in cattle, diverges from findings by [13], who reported high rates in cattle. According to the author, in China, direct contact with sheep and other ruminants promotes an increase in disease seroprevalence in cattle, with *Culicoides* serving as the primary transmission vectors.

The spatial and temporal distribution of the mosquito *Culicoides imicola* is crucial for identifying risk areas for disease spread. The SAR-Lag model suggests that higher temperatures may limit outbreak occurrences, possibly due to adverse effects on the population dynamics of the vector mosquito. Monthly risk maps based on climatic and environmental variables can help allocate surveillance and control resources more effectively. These maps are particularly useful for identifying periods and areas with low or no vector activity, enabling more targeted surveillance efforts [14].

In this context, climate change may increase the risk of regular bluetongue virus outbreaks in the United Kingdom by 2050, due to optimal temperature profiles for mosquito bites and vector longevity [15]. Climate changes, land use modifications, trade and livestock practices, the emergence of new *Culicoides* species, and wild reservoir hosts have all been implicated in transmission dynamics, highlighting the evolving nature of pathogen-vector-host interactions [10].

Temperature, humidity, wind, and precipitation affect the survival [16] and activity [17] of adult *Culicoides*. Temperature is a critical factor influencing the presence and activity of *Culicoides imicola* [18]. The survival of *Culicoides* tends to increase in milder temperatures, as temperature directly impacts the insect's population dynamics, influencing its developmental stages [19]. Studies show that vector presence is positively correlated with minimum temperatures between 11.5°C and 16°C [20], emphasizing the importance of this climatic factor for vector proliferation. Temperatures between 26°C and 33°C are ideal for the survival and development of *Culicoides brevitarsis* larvae, with increased mortality above 35.5°C, potentially reducing adult populations in northern Australia's tropics during summer months [21].

Regarding the impact of climatic conditions on bluetongue distribution, studies in China by [22] found that annual mean temperature and precipitation in the wettest month are key variables affecting the habitat of *Culicoides*, the primary bluetongue vector. These climatic conditions were identified as determinants for maintaining the vector in bioclimatic zones suitable for disease persistence. Similarly, [23] observed that the greater abundance of *Culicoides* species during warmer seasons and at lower altitudes indicated dependence on temperature and precipitation in this region, with moderate precipitation predominating in summer.

The slight positive impact of precipitation highlighted in the SAR-Lag regression model aligns with studies pointing to precipitation as a factor promoting the proliferation of hematophagous vectors like *Culicoides spp.*. For example, [24] noted that the main factors contributing to the distribution of *Culicoides orientalis* in Sikkim were annual precipitation (78.8%), followed by precipitation during the driest quarter (8.3%) and the average temperature of the warmest quarter (3.3%). Similarly, [25] reported greater mosquito richness and abundance during the rainy season. However, [26] found no association between precipitation and

Culicoides species richness, while [27] observed a negative association between precipitation and *Culicoides* abundance.

The marginally significant association of wind may reflect the indirect influence of airflow on vector dispersion or disease spread. Studies suggest that wind intensity can impact disease occurrence. For instance, [28] observed that *Culicoides* species can be transported by wind over long distances, as shown in wind trajectory analyses associated with bluetongue outbreak patterns. In the Netherlands, according to [29], the core transmission of bluetongue had a long-range spatial reach (tens of kilometers), indicating that, beyond short-distance dispersal by infected hematophagous mosquitoes, other transmission routes, such as livestock movement, likely play an important role in outbreak dispersion.

Regarding the role of wind in bluetongue virus dissemination, [30] reported that wind density data are strongly correlated with the pattern of asymmetrical horizontal spread of the causative agent, enabling medium- to long-distance propagation. Similarly, [31] established a strong positive correlation between wind density data and the asymmetric horizontal spread pattern of the bluetongue virus epidemic. The authors concluded that the mosquito's lower active flight speed (0.13 to 0.5 m s−1) virtually eliminated its role in upwind movement, particularly as modeled wind speeds were generally higher than mosquito flight speeds.

V. Conclusion

The study concludes that the presence of BTV in Brazil is limited to a few Federative Units and occurs sporadically, with higher prevalence in sheep located in temperate and humid regions during the rainy season, which favors the proliferation of *Culicoides* vectors. The significant negative relationship between mean annual temperature and outbreaks suggests that high environmental temperatures may limit disease cases, while precipitation and wind show positive associations.

The research highlights the importance of climatic variables in the distribution of bluetongue outbreaks in Brazil, suggesting targeted surveillance actions primarily for small ruminants, both wild and domestic, as a containment and monitoring measure for the disease. Further studies are needed to analyze the influence of other environmental and ecological variables involved in the dissemination of the bluetongue virus.

References

[1]   Brasil. Ministério Da Agricultura E Pecuária. Ficha Técnica Língua Azul (2020). Dez 2020.
[2]   Brasil. Ministério Da Agricultura E Pecuária. Instrução Normativa N° 50 De 24 Set. 2013.
[3]   World Organisation For Animal Health (Woah). Diseases. Bluetongue. 2024.
[4]   Subhadra S, Vijayakumar P, Ajitkumar K, Jayakumar C, Kumar Ss, Subhash N. Bluetongue Virus: Past, Present, And Future Scope. J Infect Dev Ctries. 2023;17(2):147-156.
[5]   Rivera Na, Gibbs Ep, Gardner Ia, Et Al. Bluetongue And Epizootic Hemorrhagic Disease In The United States Of America At The Wildlife–Livestock Interface. Pathogens. 2021;10(7):915.
[6]   Lager I. Bluetongue Virus In South America: Overview Of Viruses, Vectors, Surveillance And Unique Features. Vet Ital. 2004;40(3):89-93.
[7]   Legisa D, Gonzalez F, Santos M. Bluetongue Virus In South America, Central America And The Caribbean. Virus Res. 2014;182:87-94. Doi:10.1016/J.Virusres.2013.10.030.
[8]   Verdezoto J, Bréard E, Viarouge C, Et Al. Novel Serotype Of Bluetongue Virus In South America And First Report Of Epizootic Haemorrhagic Disease Virus In Ecuador. Transbound Emerg Dis. 2018;65:244-247. Doi:10.1111/Tbed.12625.
[9]   Labadie T, Sullivan E, Roy P. Multiple Routes Of Bluetongue Virus Egress. Microorganisms. 2020;8(7):965.
[10]   Purse Bv, Carpenter S, Venter G, Bellis G, Mullens Ba. Bionomics Of Temperate And Tropical Culicoides Midges: Knowledge Gaps And Consequences For Transmission Of Culicoides-Borne Viruses. Annu Rev Entomol. 2015;60:373-392. Doi:10.1146/Annurev-Ento-010814-020614.
[11]   Brasil. Ministério Da Agricultura E Pecuária. Sistema Nacional De Informações Zoosanitárias – Siz. 2024.Available From: Https://Mapa-Indicadores.Agricultura.Gov.Br/Publico/Extensions/Saude_Animal/Saude_Animal.Html
[12]   Brasil. Ministério Da Agricultura E Pecuária. Instituto Nacional De Meteorologia (Inmet). Normais Climatológicas Do Brasil 1991-2020. 2024. Available From: Https://Portal.Inmet.Gov.Br/Normais
[13]   Gong Ql, Liu Zy, Wang Ym, Et Al. Seroprevalence And Risk Factors Of The Bluetongue Virus In Cattle In China From 1988 To 2019: A Comprehensive Literature Review And Meta-Analysis. Front Vet Sci. 2021;7:550381.
[14]   Cuellar A, Kjær L, Baum A, Et Al. Altitudinal Variation And Bio-Climatic Variables Influencing The Potential Distribution Of Culicoides Orientalis Macfie, 1932, Suspected Vector Of Bluetongue Virus Across The North Eastern Himalayan Belt Of Sikkim. Acta Trop. 2017;176:402-411. Doi:10.1016/J.Actatropica.2017.09.008.
[15]   Brand S, Keeling Mj. The Impact Of Temperature Changes On Vector-Borne Disease Transmission: Culicoides Midges And Bluetongue Virus. J R Soc Interface. 2017;14:20160481. Doi:10.1098/Rsif.2016.0481.
[16]   Wittmann Ej, Mellor Ps, Baylis M. Effect Of Temperature On The Transmission Of Orbiviruses By The Biting Midge, Culicoides Sonorensis. Med Vet Entomol. 2002;16:147-156.
[17]   Carpenter S, Szmaragd C, Barber J, Et Al. An Assessment Of Culicoides Surveillance Techniques In Northern Europe: Have We Underestimated A Potential Bluetongue Virus Vector? J Appl Ecol. 2008;45:1237-1245.
[18]   Lysyk Tj, Danyk T. Effect Of Temperature On Life History Parameters Of Adult Culicoides Sonorensis (Diptera: Ceratopogonidae) In Relation To Geographic Origin And Vectorial Capacity For Bluetongue Virus. J Med Entomol. 2007;44:741-751.
[19]   White Sm, Sanders Cj, Shortall Cr, Purse Bv. Mechanistic Model For Predicting The Seasonal Abundance Of Culicoides Biting Midges And The Impacts Of Insecticide Control. Parasit Vectors. 2017;10:2097. Doi:10.1186/S13071-017-2097-5.
[20]   Tilibaşa E, Dărăbuş G. Preliminary Studies On Dynamics Of Culicoides Spp. In Western Romania In Conjunction With Some Environmental Factors. Parasit Vectors. 2014;7(S1):O7. Doi:10.1186/1756-3305-7-S1-O7.

[21]   Allingham P. Effect Of Temperature On Late Immature Stages Of Culicoides Brevitarsis (Diptera: Ceratopogonidae). J Med Entomol. 1991;28(6):878-881. Doi:10.1093/Jmedent/28.6.878.
[22]   Zhong J, Wang H, Zhang Y, Et Al. Prediction And Transmission Analysis Of Bluetongue Disease In China. Prev Vet Med. 2024;230:106290.
[23]   Lakew B, Nicholas A, Walkden-Brown Sw. Spatial And Temporal Distribution Of Culicoides Species In The New England Region Of New South Wales, Australia Between 1990 And 2018. Plos One. 2021;16:E0249468. Doi:10.1371/Journal.Pone.0249468.
[24]   Mukhopadhyay E, Hazra S, Saha G, Banerjee D. Altitudinal Variation And Bio-Climatic Variables Influencing The Potential Distribution Of Culicoides Orientalis Macfie, 1932, Suspected Vector Of Bluetongue Virus Across The North Eastern Himalayan Belt Of Sikkim. Acta Trop. 2017;176:402-411. Doi:10.1016/J.Actatropica.2017.09.008.
[25]   Gusmão G, Brito G, Moraes L, Abreu Bandeira Mc, Rebêlo J. Temporal Variation In Species Abundance And Richness Of Culicoides (Diptera: Ceratopogonidae) In A Tropical Equatorial Area. J Med Entomol. 2019;56:1013-1018. Doi:10.1093/Jme/Tjz015.
[26]   Quaglia A, Blosser E, Mcgregor B, Et Al. Tracking Community Timing: Pattern And Determinants Of Seasonality In Culicoides (Diptera: Ceratopogonidae) In Northern Florida. Viruses. 2020;12:1-12. Doi:10.3390/V12090931.
[27]   Kirkeby C, Bødker R, Stockmarr A, Lind P. Spatial Abundance And Clustering Of Culicoides (Diptera: Ceratopogonidae) On A Local Scale. Parasit Vectors. 2013;6:43. Doi:10.1186/1756-3305-6-43.
[28]   Ducheyne E, De Deken R, Bécu S, Et Al. Quantifying The Wind Dispersal Of Culicoides Species In Greece And Bulgaria. Geospat Health. 2007;1(2):177-189. Doi:10.4081/Gh.2007.266.
[29]   Boender Gj, Van Roermund Hjw, Hagenaars Tj, Et Al. Spatial Transmission Characteristics Of The Bluetongue Virus Serotype 3 Epidemic In The Netherlands, 2023. Viruses. 2024;16(4):625. Doi:10.3390/V16040625.
[30]   Hendrickx G, Gilbert M, Staubach C, Et Al. A Wind Density Model To Quantify The Airborne Spread Of Culicoides Species During North-Western Europe Bluetongue Epidemic, 2006. Prev Vet Med. 2008;87(1-2):162-181. Doi:10.1016/J.Prevetmed.2008.06.009.
[31]   Sedda L, Brown H, Purse Bv, Et Al. A New Algorithm Quantifies The Roles Of Wind And Midge Flight Activity In The Bluetongue Epizootic In Northwest Europe. Proc Biol Sci. 2012;279:2354-2362. Doi:10.1098/Rspb.2011.2555.