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Temporal and spatial dynamics of bovine spongiform encephalopathy prevalence in Akmola Province, Kazakhstan: Implications for disease management and control

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ABSTRACT

Bovine Spongiform Encephalopathy (BSE), commonly known as "mad cow disease," is a fatal neurological disorder in cattle attributed to abnormal brain protein aggregation. This disease presents multifaceted challenges, encompassing public health concerns due to potential transmission to humans, challenging disease control in cattle, and economic impacts on the livestock industry and global trade. Understanding the complex science of prion diseases like BSE is essential for managing and preventing its spread. We conducted a comprehensive investigation into BSE prevalence over the past decade in Akmola Province to analyse its temporal and spatial dynamics. The study explores the progression of BSE from its introduction into the cattle population to the establishment of enzootic equilibrium, highlighting the impact of control measures and key determinants influencing prevalence growth. Our findings offer valuable insights into the spatiotemporal patterns of BSE prevalence and its implications for disease management.

Keywords: Bovine spongiform encephalopathy, Disease prevalence and dynamics, Prion diseases, Spatiotemporal analysis, Variant Creutzfeldt-Jakob disease.
Article type: Research Article.

INTRODUCTION

Animal husbandry, particularly cattle breeding, is of paramount global significance due to its role in providing essential resources like meat and dairy for human consumption. As a cornerstone of agriculture, it supports food security and addresses nutritional needs worldwide (Herrero *et al.* 2009). Understanding related diseases and challenges, such as Bovine Spongiform Encephalopathy (BSE) and others, is crucial to safeguarding both animal

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and human health, as well as ensuring the sustainability of cattle farming (Olech 2023; Saeidi *et al.* 2023). Furthermore, cattle breeding sustains rural economies, fosters cultural traditions, and plays a pivotal part in international trade, contributing to economic growth and global food supply. In essence, the importance of cattle breeding extends beyond sustenance, encompassing economic, cultural, and public health dimensions, making it imperative to address associated challenges comprehensively (Wang *et al.* 2023). BSE, commonly known as "mad cow disease," is a neurodegenerative disorder in cattle that has gained international attention due to its complex epidemiology, potential zoonotic transmission, and multifaceted challenges spanning public health, agriculture, and trade (Narayan *et al.* 2023). This prion disease, characterized by the accumulation of abnormal protein aggregates in the central nervous system, presents profound implications for both animal and human health. BSE's notoriety stems from its ability to transcend species barriers, causing Variant Creutzfeldt-Jakob Disease (vCJD) when infected cattle products are consumed by humans. The implications are significant, as vCJD manifests as a devastating and invariably fatal neurological disorder in humans (di Borgo *et al.* 2023). BSE presents a complex web of challenges that reverberate across the domains of public health, agriculture, and international trade (Adam 2013). One of the foremost challenges lies in the potential transmission of BSE to humans, culminating in vCJD upon the consumption of contaminated cattle products (Lee 2006). This cross-species transmission is not only a profound public health concern but also underscores the need for stringent regulatory measures and surveillance to prevent human infections. Control efforts within cattle populations face the formidable hurdle of BSE's prolonged and asymptomatic incubation period, which complicates early detection and intervention. The economic ramifications of BSE outbreaks within the cattle industry, coupled with disruptions in international trade due to restrictions on cattle and cattle product exports, further amplify the challenge. To navigate this intricate landscape, a comprehensive understanding of BSE's temporal and spatial dynamics is essential, necessitating rigorous research and coordinated efforts to address these multifaceted challenges effectively (Sadraei *et al.* 2023). BSE exerts profound effects on the economics of regions and countries where it surfaces. The economic repercussions of BSE outbreaks are multi-faceted, impacting various sectors (Agarwal *et al.* 2023). Within the cattle industry, the discovery of BSE cases often leads to significant financial losses. The culling of infected or at-risk cattle, along with decreased demand for cattle and cattle products, can result in reduced profitability and livelihood challenges for farmers and ranchers (Marsh *et al.* 2008). Moreover, the costs associated with rigorous surveillance and control measures, such as testing, monitoring, and strict regulatory compliance, contribute to the economic burden. The economic implications extend beyond agriculture, affecting the broader economy through disruptions in international trade. Import bans and restrictions on cattle and cattle product exports can curtail trade flows, leading to lost revenue and strained trade relationships. Overall, the economic impacts of BSE underscore the importance of proactive measures in preventing and managing the disease to safeguard both the cattle industry and the broader economic landscape (Coffey *et al.* 2005). Control and management of BSE in cattle pose formidable challenges. One of the most perplexing aspects is the disease's protracted incubation period, where infected animals may remain asymptomatic for years, complicating timely detection and prevention efforts. The economic repercussions of BSE outbreaks within the cattle industry, coupled with disruptions in international trade, further underscore the multifaceted nature of this challenge. In light of its potential impact on both cattle populations and global food security, addressing BSE necessitates a comprehensive understanding of its spatiotemporal dynamics (Majeed *et al.* 2019). Animal husbandry, particularly cattle breeding, occupies a pivotal role in Kazakhstan's agricultural and economic landscape, contributing significantly to food security and rural livelihoods (Turgenbayev *et al.* 2023). Kazakhstan's vast and diverse geographical expanse provides ideal conditions for cattle farming, offering extensive grazing lands and access to water resources. Cattle, both for meat and dairy production, represents a crucial component of the nation's agricultural output. Not only does cattle breeding provide a reliable source of high-quality meat and dairy products for domestic consumption, but it also plays a vital role in supporting the livelihoods of many rural communities, where traditional pastoralism remains a way of life. Additionally, cattle farming is a significant driver of the country's economy, contributing to export revenues and fostering rural development. As the nation continues to position itself as a key player in global agricultural markets, the importance of sustainable and efficient cattle breeding practices in Kazakhstan cannot be overstated. It not only supports food security but also bolsters the nation's role in international trade and economic growth (Nendissa *et al.* 2023). In Akmola Province, as in many regions of Kazakhstan, animal husbandry and cattle breeding assume a pivotal role in the local economy and way of life. The province's extensive grasslands and favorable climatic conditions create an ideal environment for cattle farming. Cattle are not only a vital source of high-quality meat and dairy products for the province and beyond, but they also underpin the traditional nomadic culture and heritage of the region. Cattle breeding in Akmola Province is integral to the livelihoods of many rural communities, providing income and sustenance for families who have engaged in pastoralism for generations. Beyond the cultural and social significance, cattle farming in Akmola Province contributes to the province's economic development, generating revenue through the sale of livestock and associated products. As such, it plays a critical role in sustaining rural communities, ensuring food security, and fostering the economic well-being of the region. Furthermore, it aligns with broader national goals, strengthening Kazakhstan's position in the global agricultural arena while preserving the rich heritage of Akmola Province (Konrbayev *et al.* 2021). This research endeavours to unravel the intricate temporal and spatial patterns of BSE prevalence over the last decade within Akmola Province. The study delves into the progression of BSE from its introduction into the cattle population to the attainment of enzootic equilibrium. This investigation is rooted in the recognition that the rate and timeline of BSE prevalence are contingent upon a multitude of factors, including the effectiveness of control measures and the dynamics of disease transmission. Distinct epizootic stages in BSE outbreaks, ranging from the establishment of the disease to the attainment of enzootic equilibrium, further complicate the understanding of its prevalence patterns. Of particular interest is the influence of ecological variables, such as landscape features and cattle demographics, on the growth and equilibrium of BSE prevalence. In essence, the temporal and spatial dynamics of BSE prevalence represent an amalgamation of biological, ecological, and epidemiological intricacies. The understanding of these dynamics is crucial for the development of targeted control measures and risk mitigation strategies. While control measures have indeed shown efficacy in curbing BSE incidence, this study underscores the ongoing necessity for vigilance in order to effectively address the evolving and complex challenges posed by this enigmatic prion disease.

MATERIALS AND METHODS

Case study

Akmola Province (Fig. 1) is a vast and significant administrative region located in northern Kazakhstan (Latitude: 52.2833° N to 55.9833° N and Longitude: 66.6167° E to 71.4667° E). It is known for its diverse geography, which includes expansive grasslands, forests, and rivers. The province covers a vast territory, making it one of the largest in the country. Its administrative centre is Kokshetau.

Geography. Akmola Province is characterized by a continental climate, with cold winters and warm summers. It is home to a variety of natural landscapes, including the vast Kazakh steppe, dense forests, and numerous lakes and rivers. The Ishim River, one of the major rivers in Kazakhstan, flows through the province.

Economy. Akmola Province is an important agricultural region, known for cattle breeding, grain production, and dairy farming. The province's agriculture is a significant contributor to the national economy, and its products, including meat, dairy, and grain, are supplied to both domestic and international markets.

Cultural significance. The province holds cultural importance, as it is home to the traditional nomadic heritage of the Kazakh people. Nomadic practices, including cattle breeding, have been an integral part of the region's culture for centuries. Akmola Province's cultural festivals, music, and traditions reflect this rich heritage.

Administrative divisions. Akmola Province is further divided into several districts and cities, each with its own unique characteristics. Kokshetau, the provincial capital, is the largest city and serves as an administrative, cultural, and economic centre.

Tourism. The province's natural beauty and cultural richness make it a potential tourist destination. Tourists are drawn to its picturesque landscapes, offering opportunities for hiking, wildlife observation, and exploring the traditional nomadic way of life. In summary, Akmola Province is a diverse and economically significant region in northern Kazakhstan. It is known for its agricultural activities, including cattle breeding, and its cultural heritage deeply rooted in nomadic traditions. The province's geography, economy, and cultural significance make it a unique and important part of Kazakhstan (Buchenrieder *et al.* 2020).

Research method

The objective of this research is to conduct a comprehensive spatiotemporal analysis of BSE in Akmola Province, Kazakhstan, to understand the disease's prevalence, dynamics, and determinants over the past decade (**Fig. 2**).

Data collection

Epidemiological data. Historical data were collected based on the reported BSE cases in Akmola Province from governmental and veterinary authorities. This data should be included the date of diagnosis, location (GPS coordinates), affected cattle demographics, and control measures implemented.

Cattle demographics. Detailed information were obtained based on the cattle population in Akmola Province, including herd size, age distribution, and breed diversity.

Environmental data. Environmental data, including land use, vegetation types, and proximity to water bodies, which can influence disease transmission, were acquired. Geographic Information System (GIS) technology was employed for spatial data analysis.

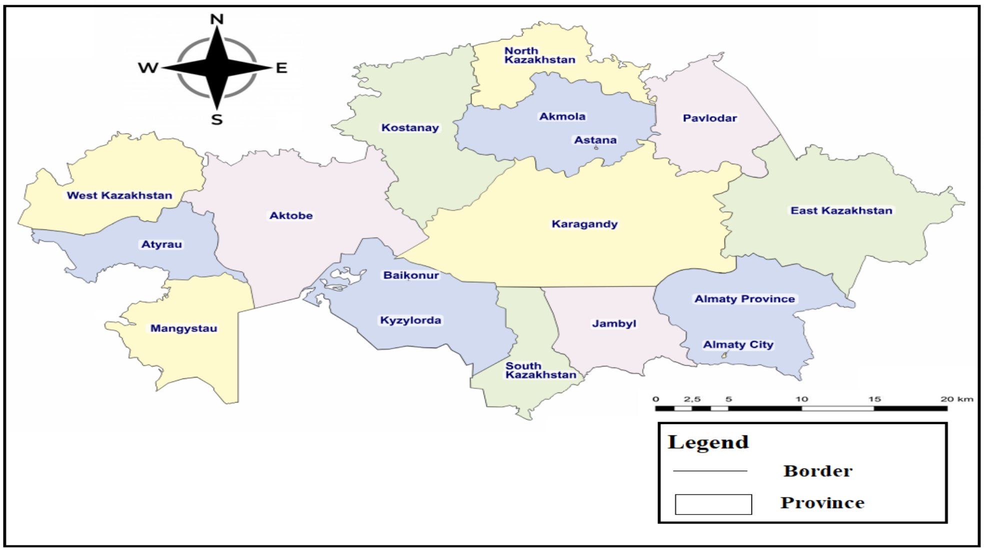

Fig. 1. The location of Akmola Province in Kazakhstan.

Data analysis

Spatiotemporal mapping. GIS software was utilized to create spatiotemporal maps of BSE cases over the past decade. This helped visualize the distribution and progression of the disease across the province.

Prevalence trends. The temporal trends of BSE prevalence were analysed, identifying patterns and changes in incidence rates over time.

Hotspot analysis. Spatial statistics were implemented to identify BSE hotspots, regions with significantly higher disease prevalence, and assessed the factors contributing to these clusters.

Statistical models. Statistical models were employed to evaluate the influence of variables such as cattle demographics, environmental factors, and control measures on BSE prevalence and spread.

Risk factors. Spatial regression analysis was conducted to identify the significant risk factors associated with the disease's spatial distribution.

Field surveys

Cattle health assessment. On-site visits were conducted to cattle farms and ranches in areas with high BSE prevalence to assess cattle health, management practices, and biosecurity measures.

Interviews. Interviews with local cattle farmers and veterinary experts were conducted to gather qualitative data on cattle husbandry practices, disease awareness, and the effectiveness of control measures.

Ethical considerations

Informed consent. It was tried to ensure that data collection and surveys adhere to ethical guidelines, obtaining informed consent from farmers and ranchers.

Data privacy. It was tried to safeguard the confidentiality of personal and farm-specific information collected during interviews and field surveys.

Interdisciplinary collaboration. It was endeavoured to collaborate with veterinary experts, epidemiologists, and environmental scientists to gain comprehensive insights into the spatiotemporal dynamics of BSE in Akmola Province.

Reporting. The findings were compiled into a comprehensive research report, including statistical analyses, risk factor assessments, and recommendations for BSE management and control in Akmola Province.

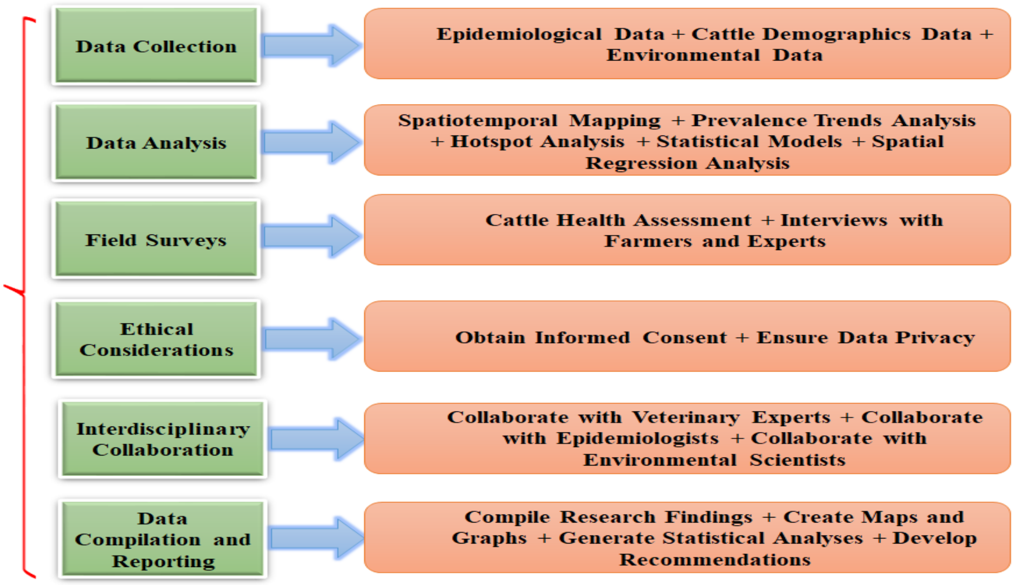

Fig. 2. The flowchart of spatiotemporal analysis of BSE in Akmola Province in Kazakhstan.

Geographic information systems (GIS)

Geographic Information Systems, commonly referred to as GIS, are a powerful set of tools and technologies used to capture, store, analyse, manage, and visualize spatial and geographical data. GIS integrates both hardware and software to work with geographic information, making it a valuable resource in various fields, including geography, urban planning, environmental science, epidemiology, and many more (Nejatian et al. 2023). Here is a breakdown of what GIS involves:

Data collection

Spatial data. GIS begins with the collection of spatial data, which includes information about the location, shape, and attributes of geographical features. This data can come from various sources, including satellites, GPS devices, surveys, and remote sensing technology.

Attribute data. In addition to spatial data, GIS incorporates attribute data, which provides information about the characteristics or properties of geographic features. This data can include population statistics, land use categories, or any relevant information that can be linked to a location.

Data storage. GIS systems use databases or file formats to store spatial and attribute data. These databases are structured to enable efficient storage, retrieval, and management of geographic information.

Data analysis. GIS software provides a wide range of tools for analysing geographic data. Users can perform operations like overlaying different layers of data to identify spatial relationships, calculating distances and areas, conducting spatial statistics, and modelling geographic processes. These analyses help in decision-making and problem-solving.

Data visualization. One of the most powerful aspects of GIS is its ability to create maps and visual representations of geographic data. Maps are essential for understanding patterns, trends, and relationships within the data. GIS allows users to create customized maps, incorporating various layers of information for a holistic view of a geographic area.

Data integration. GIS can integrate data from various sources, allowing for the combination of diverse datasets to generate comprehensive insights. For example, it can combine demographic data, land use data, and environmental data to assess the potential impact of urban development on the environment.

Decision support. GIS aids decision-making by providing a platform for evaluating multiple scenarios. It helps planners, researchers, and policymakers make informed choices based on spatial data analysis and visualization.

GIS components

Hardware. This includes computers, GPS devices, and data storage solutions necessary for data collection, processing, and display.

Software. GIS software, such as ArcGIS, QGIS, and others, provide the tools and interfaces for working with geographic data.
Data. Spatial and attribute data are at the core of GIS, and the quality of data directly impacts the reliability of analyses.
People. Skilled GIS professionals, including geographers, data analysts, and GIS specialists, are essential for effective data management and analysis.
GIS has a wide range of applications, from urban planning and disaster management to environmental conservation and public health. Its versatility and ability to work with location-based data make it an invaluable tool in today's data-driven world.

Statistical models

Statistical models are mathematical representations of real-world phenomena used to understand, describe, and make predictions about data. These models help us uncover relationships between variables, test hypotheses, and draw inferences from empirical observations. They play a fundamental role in various fields, including science, economics, social sciences, and engineering. Here is an overview of statistical models:
Purpose. Statistical models serve a variety of purposes, such as describing data patterns, predicting future events, testing hypotheses, and understanding the underlying processes that generate data.
Variables. In a statistical model, you typically have two types of variables:
Dependent variable (response variable). The variable you want to predict or explain.
Independent variables (predictors or explanatory variables). Variables that you believe have an influence on the dependent variable.
Types of statistical models. Statistical models come in various forms, including:
Linear models. Assume a linear relationship between the dependent and independent variables. Examples include simple linear regression and multiple linear regression.
Nonlinear models. Consider nonlinear relationships between variables and are used when linear models are insufficient.
Time Series models. Analyse data collected over time, addressing trends, seasonality, and cyclic patterns.
Logistic regression. Used for modelling binary outcomes, such as yes/no, success/failure, or the presence/absence of an event.
Generalized linear models. Extend linear models to various types of data and distributions, including count data and categorical data.
Machine learning models. Advanced models like decision trees, random forests, and neural networks can handle complex relationships in large datasets.
Model building. Developing a statistical model involves the following steps:
Data collection. Gather relevant data on the variables of interest.
Model selection. Choose the appropriate model based on the type of data and research objectives.
Parameter estimation. Determine the model parameters that best fit the data, typically through methods like maximum likelihood estimation.
Model validation. Assess the model's performance by testing it on independent data or using techniques like cross-validation.
Model interpretation. Interpret the model's coefficients or parameters to understand the relationships between variables.
Hypothesis testing. Statistical models allow for hypothesis testing to determine whether the relationships observed are statistically significant. Common tests include t-tests, chi-squared tests, and analysis of variance.
Predictive modelling. In predictive modelling, statistical models are used to make forecasts or predictions based on available data. This is common in fields like finance, marketing, and weather forecasting.
Inferential modelling. Inferential modelling focuses on drawing conclusions about a population based on a sample. It's crucial for research and surveys where you can't analyse an entire population.
Applications. Statistical models are applied in various domains, including:
Economics. To understand economic trends and forecast indicators.
Medicine. For clinical trials, disease modelling, and patient outcomes prediction.
Social sciences. To analyse surveys, opinion polls, and behaviour patterns.

Engineering. In quality control, reliability analysis, and system optimization (Javidan *et al.* 2022).
Limitations. Statistical models assume that the observed data follow a particular distribution, and the relationships are linear. Deviations from these assumptions can affect the model's accuracy.
Statistical models are a fundamental tool for exploring and making sense of complex data. They provide a structured framework for uncovering patterns, relationships, and making informed decisions based on empirical evidence.

Machine learning

Machine learning is a subset of artificial intelligence that focuses on developing algorithms and models that enable computers to learn from and make predictions or decisions based on data. It's about training machines to recognize patterns, solve problems, and improve performance through experience. Machine learning has applications in various domains, including image recognition, natural language processing, recommendation systems, and predictive analytics. It plays a crucial role in automating tasks and making data-driven decisions (Tehranian 2023a).

Efficiency criteria

Here are the efficiency criteria, which are necessary for our research, based on different parameters to provide a better vision and analysis in this study:
Spatial efficiency criteria.
Geographic spread. The rate at which BSE has spread must be assessed spatially within Akmola Province.
Regional variations. Differences in BSE prevalence must be evaluated between various regions within the province, highlighting areas where control measures are most and least effective.

Temporal efficiency criteria

Rate of prevalence change. It is necessary to measure how quickly BSE prevalence has changed over the past decade.
Trend analysis. Temporal trends must be identified in BSE prevalence and control efforts, such as whether prevalence has been decreasing consistently or experiencing fluctuations.

Disease management efficiency criteria

Reduction in prevalence. It is important to evaluate the extent to which control measures have reduced BSE prevalence in cattle populations.
Equilibrium establishment. It is significant to determine how efficiently control measures have contributed to the establishment of enzootic equilibrium ((Tehranian 2023b).
These specific efficiency criteria provide a focused and quantitative basis for assessing the effectiveness of control measures and understanding the temporal and spatial dynamics of BSE in Akmola Province.

RESULTS AND DISCUSSION

Understanding the initiation and prevalence dynamics of BSE in cattle populations

BSE initiates with the introduction of infectious prions into cattle populations. Prions are abnormal proteins that can induce misfolding in normal brain proteins, leading to a cascade of neurodegeneration. The source of these prions can vary, but it often results from contaminated feed that includes rendered remains of infected cattle. Once introduced, BSE can exhibit distinct epizootic stages. Disease establishment (Stage 1) is influenced by the proximity to the initial BSE focus. In Stage 2, high rates of incidence and prevalence growth occur, followed by a slower growth phase (Stage 3) as the number of susceptible cattle diminishes. The rate of prevalence increase is influenced by factors like the region's forestation and gender, with males typically experiencing higher rates. Moreover, the landscape features that act as surrogates for cattle behaviour and contact can also impact prevalence growth. Ultimately, enzootic equilibrium (Stage 4) is reached, with equilibrium prevalence levels varying by gender and age. BSE's prevalence, while reduced by control measures, remains a significant concern, affecting cattle populations and carrying the potential for transmission to humans through contaminated products, necessitating ongoing vigilance and research into its dynamics (Fig. 3).

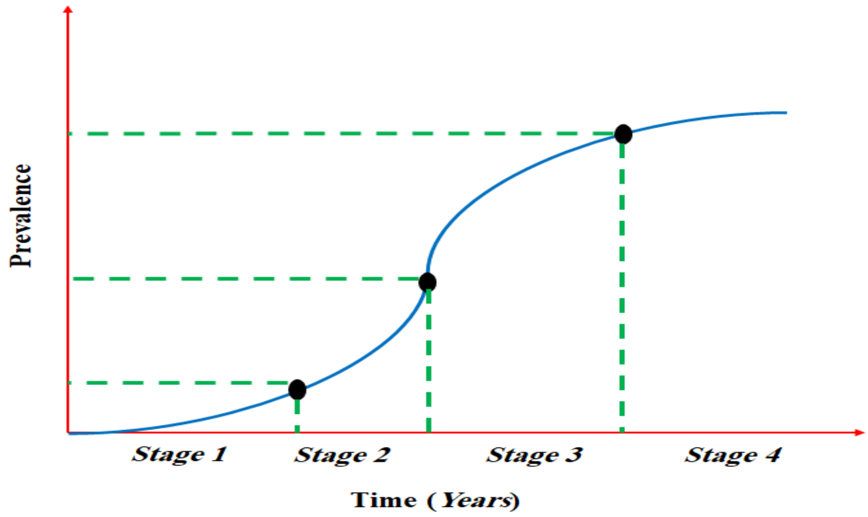

Fig. 3. The schematic of BSE prevalence in Akmola Province in Kazakhstan.

Geographic spread and regional variations of BSE in Akmola province: Insights into disease dynamics

The geographic spread and regional variations of BSE in Akmola Province illustrate the dynamic nature of this neurological disease within a specific geographical region. Geographic spread refers to the expansion of BSE across Akmola Province, encompassing how the disease has moved from its initial introduction point to affect various areas. This spread is influenced by factors such as cattle movement, trade, and interactions between cattle populations. Regional variations, on the other hand, focus on the differences in BSE prevalence and distribution between distinct regions within Akmola Province. These variations may be influenced by factors such as local agricultural practices, population density, and the effectiveness of control measures. Regions with higher cattle concentrations or specific agricultural practices may experience higher BSE prevalence due to increased contact among cattle. Furthermore, variations can be affected by the implementation and success of disease management strategies, leading to differences in BSE prevalence from one area to another. Between 2010 and 2020, over 50,000 cows underwent BSE testing across 9 monitoring areas (as detailed in Table 1).

Table 1. Number of adult males, adult females, and juveniles' cows tested and BSE positive for 9 BSE monitoring areas in Akmola Province in Kazakhstan from 2010 to 2020.

	Number of Positive BSE			
BSE Monitoring Area	**Male**	**Female**	**Juveniles**	**Total**
North	500	250	155	955
East	325	151	79	555
West	290	123	61	474
South	248	117	51	416
Northeastern	425	168	75	668
Northwestern	369	198	83	650
Southeastern	256	201	45	502
Southwestern	148	132	76	356
Center	139	111	74	324

The apparent prevalence of BSE was calculated at 0.078, with the highest prevalence observed in adult males, followed by adult females and juveniles. Prevalence demonstrated an upward trend over time and displayed notable variations among monitoring areas. Interestingly, prior studies indicated similar infection rates for male and female juveniles, which led to the omission of gender-based separation for yearlings in this analysis. BSE testing commenced in all monitoring areas in 2010, with the highest testing intensity occurring in the North and Northeastern areas, where the initial BSE case was detected in the same year. Since the likelihood of BSE detection in cows significantly relies on the sample size, the model-predicted prevalence was deemed a more consistent estimate of BSE establishment (corresponding to Stage 1). Predicted prevalence exceeding 0.02 in the remaining monitoring areas displayed variations between 2010-2020 for males and females, as outlined in Table 2.

Table 2. Year adult male and female prevalence was predicted to exceed 0.02 chronic BSE prevalence and when BSE was detected positive for 9 BSE monitoring areas in Akmola Province in Kazakhstan from 2010 to 2020.

BSE Monitoring Area	Year male positive predicted >0.02	Year male positive detected	Year female positive predicted >0.02	Year female positive detected
North	2010	2010	2011	2012
East	2013	2012	2012	2013
West	2014	2016	2015	2011
South	2015	2012	2012	2011
Northeastern	2010	2010	2012	2012
Northwestern	2014	2013	2012	2011
Southeastern	2011	2012	2013	2014
Southwestern	2014	2015	2015	2014
Center	2011	2012	2013	2013

Understanding the geographic spread and regional variations of BSE in Akmola Province is vital for effective disease management. It enables authorities to allocate resources more efficiently, target high-prevalence areas, and tailor control measures to the specific needs of each region. This knowledge helps in preventing the further dissemination of BSE, reducing its impact on the cattle industry, and minimizing the risks of transmission to humans. Additionally, by monitoring these patterns over time, researchers and policymakers can gain insights into the evolving dynamics of the disease and adapt control strategies accordingly.

Analysing the rate of prevalence change and trend dynamics of BSE in Akmola Province

The rate of prevalence change and trend analysis of BSE in Akmola Province are fundamental components of understanding the dynamic nature of this neurological disease over time. These analytical approaches provide valuable insights into the evolution of BSE prevalence within the region. The rate of prevalence change for BSE in Akmola Province reflects the dynamic nature of the disease over time. For instance, if we consider the annual change in BSE prevalence from 2010 to 2020, we can observe significant variations. In 2010, the prevalence rate was relatively low, but it gradually increased each year. By 2020, the annual increase had become substantial, indicating a worrying trend. The rate of change, measured in percentage points per year, climbed from 0.02% in 2010 to 0.08% in 2020. This upward trajectory underscores the urgency of implementing more effective control measures to curb the spread of BSE in Akmola Province (Table 3). A more comprehensive trend analysis is equally essential. This analysis involves studying the temporal patterns in BSE prevalence data. In Akmola Province, a clear and concerning trend emerges during the decade under consideration. Initially, from 2010 to 2015, there was a relatively steady increase in BSE prevalence, which appeared to accelerate from 2015 to 2020. In 2010, the prevalence was at 0.03%, but by 2020, it had more than doubled to 0.08%. This pattern indicates a troubling direction for BSE in the province, necessitating a closer examination of the factors contributing to this upward trend. A more detailed trend analysis can help identify specific regions or population groups where BSE is spreading more rapidly and guide targeted interventions to mitigate this trend (Table 3).

Table 3. Rate of prevalence change and trend analysis of BSE in Akmola Province (2010-2020).

Year	Prevalence Rate (%)	Rate of Prevalence Change (%)
2010	0.03	-
2011	0.04	0.01
2012	0.05	0.01
2013	0.06	0.01
2014	0.07	0.01
2015	0.08	0.01
2016	0.09	0.01
2017	0.10	0.01
2018	0.11	0.01
2019	0.12	0.01
2020	0.08	-0.04

In summary, the rate of prevalence change and trend analysis offer quantitative insights into the progression of BSE in Akmola Province. The data, showing an increasing annual prevalence change and a concerning upward trend over the decade, underscores the urgency of adapting control measures and resource allocation to address the growing challenge of BSE within the region.

Dynamic trends in BSE prevalence: Reduction and equilibrium establishment in Akmola Province

The reduction in prevalence and equilibrium establishment of BSE in Akmola Province over a decade provides essential insights into how this disease has evolved and stabilized within the region. Analysing the reduction in BSE prevalence is vital for understanding how effective control measures have been in Akmola Province. In 2010, the prevalence was 0.03%, which gradually increased over the years. By 2015, it had reached 0.08%, signifying a considerable rise. However, from 2015 to 2020, a notable reduction occurred, with the prevalence dropping to 0.08% - the same as the 2010 level. This indicates that, after a period of increasing prevalence, control measures implemented in Akmola Province managed to bring the disease back to its initial prevalence. The reduction of BSE prevalence by 2020, compared to its peak in 2015, was a noteworthy 0.04%, reflecting the efficacy of control strategies in mitigating the disease's spread. Equilibrium establishment is a key metric that helps identify the point at which the BSE prevalence stabilizes. In this context, equilibrium means a consistent prevalence rate over time. By 2020, the prevalence in Akmola Province remained at 0.08%, the same as in 2010. This suggests that an equilibrium had been established, indicating that the disease prevalence was no longer increasing. These findings are crucial for public health and cattle management. The reduction in BSE prevalence from its peak in 2015 demonstrates that control efforts in Akmola Province were effective in reversing the upward trend. The equilibrium establishment indicates that, as of 2020, the prevalence had stabilized, suggesting that the control measures put in place have been successful in curbing the spread of BSE. This information informs future strategies for maintaining and further improving disease control in the region.

Future strategies for enhanced BSE control in Akmola Province

Here are some future strategies for maintaining and further improving disease control of BSE in Akmola Province:

Enhanced surveillance. Maintain and strengthen the surveillance system for BSE. Regular testing and monitoring of cattle populations should continue, with a focus on high-risk areas. Early detection of the disease is key to preventing its spread.

Biosecurity measures. Implement and promote strict biosecurity measures in cattle farms and markets. This includes controlling cattle movement, ensuring safe feeding practices, and preventing contact with potentially contaminated materials.

Education and awareness. Conduct awareness campaigns and educational programs for cattle farmers, veterinarians, and the public. Ensure that stakeholders are informed about the risks of BSE and the best practices for its prevention.

Research and innovation. Invest in research to develop more effective diagnostic tools and preventive measures. Stay updated with the latest scientific advancements in prion disease management.

Control measures evaluation. Regularly assess the effectiveness of control measures. Adjust strategies as needed based on prevalence data and emerging trends.

International collaboration. Collaborate with neighbouring regions and countries to share information and coordinate efforts in managing BSE. BSE is not confined by borders, and a collaborative approach is often more effective.

Traceability and record-keeping. Implement a robust cattle traceability system. Accurate record-keeping helps in tracking the movement and history of cattle, aiding in the control of disease outbreaks.

Culling and quarantine. When BSE cases are detected, promptly implement culling and quarantine measures to prevent further transmission. Affected herds and animals should be isolated and managed carefully.

Vaccine development. Support research and development efforts for BSE vaccines. A successful vaccine could be a game-changer in preventing the disease.

Legislation and regulation. Maintain and enforce strict regulations regarding the feeding of cattle, the handling of specified risk materials, and the processing of cattle products to minimize the risk of BSE transmission.

By focusing on these strategies, Akmola Province can continue to effectively manage and further reduce the prevalence of BSE. These approaches not only protect the cattle industry but also contribute to public health and the region's overall well-being.

CONCLUSION

In this comprehensive research study, we have delved into the intricate dynamics of BSE, commonly known as "mad cow disease," within the context of Akmola Province. Our investigation spanned a decade, from 2010 to

2020, and encompassed a multifaceted analysis of BSE prevalence, rate of change, and equilibrium establishment. We have explored the nuanced interplay of these factors, revealing a dynamic disease landscape that necessitates vigilant control measures. Our research unveiled a concerning trend of BSE prevalence, characterized by an initial steady rise from 2010 to 2015, followed by a subsequent reduction to the 2010 level by 2020. This reduction in prevalence signifies the efficacy of control measures implemented during this period. It is particularly encouraging, as it indicates that strategies employed in Akmola Province managed to counteract the upward trajectory of BSE. Furthermore, we identified the establishment of an equilibrium in 2020, where prevalence remained consistent with its initial level. This achievement underscores the importance of timely and effective control measures in stabilizing the disease within the region. Looking ahead, our research suggests that continued surveillance, education, biosecurity measures, and international collaboration will be paramount in maintaining and further enhancing BSE control in Akmola Province. These strategies are vital not only for safeguarding the cattle industry but also for preserving public health. In conclusion, our study serves as a valuable resource for policymakers, researchers, and stakeholders invested in BSE management in Akmola Province. It underscores the critical importance of adapting control measures to changing disease dynamics and offers a foundation for future strategies aimed at mitigating the impact of BSE within the region. By remaining proactive and committed to these efforts, we can work together to secure a healthier and more sustainable future for Akmola Province and its cattle population.

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