



## Impact of geographical factors on the spread of animal brucellosis in the Republic of Kazakhstan

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### ARTICLE INFO

#### Keywords:

Cattle  
Brucellosis  
Epizootiology  
Geographic information system  
Infection

### ABSTRACT

In Latin and Central America and in most Asian countries, brucellosis remains an insufficiently studied disease. This study aims to determine the national and regional incidence of brucellosis among cattle (cows) and small ruminants (sheep, goats) in the Republic of Kazakhstan, as well as to identify the effect of climatic and geographical factors on the incidence rates. Thematic maps were created in an open geographic information system QGIS version 2.8. in order to identify the natural and socio-economic factors that influence the spread of the disease overlay method was used. Local cluster analysis was used in order to identify additional causes of the disease. Findings show the following values of Pearson correlation between the overall population and the number of animals infected: 0.68 for cows,  $p \leq 0.005$ , and 0.56 for sheep and goats,  $p \leq 0.03$ . Thus, the larger the herd in a given area, the greater likelihood of having brucellosis. Data processing reveals that Kazakhstan has almost twice as many regions good for cattle breeding as regions that are good for the small ruminants farming. The correlation variables for cattle and small ruminants are approximately the same. On the basis of the performed research the author proposes to amend the accepted methodology of epidemiology surveillance by the methods based on spatial (geographical) analysis. It is also proposed to adjust the process of breeding cattle and small ruminants considering the additional health recommendations that take into account the geographical aspects of the spread of the disease.

### 1. Introduction

Brucellosis of farm animals was a widespread ubiquitous infection in the past. But nowadays epizootic situation for this disease is still quite tense in many regions, mainly in the countries of Central, South-East, and Asia Minor, the Mediterranean, some countries of Africa and South America [1].

In the context of globalisation and the global division of labour forces, there is an increase in the exchange of goods between the states, including agricultural products. Since brucellosis can persist for quite a long time in animal products that go for export, there is a probability that the infected food products can get into the retail trade [2,3]. Mainly there are neighbouring countries in the risk zone, which are members of the Customs Union.

Most studies of brucellosis have purely medical orientation: disease

clinics [4], methods of diagnosis [5] and veterinary and sanitary measures [6]. At the same time, there is quite extensive global research practice of using interdisciplinary and especially geospatial research method [6–11]. Geographic information systems (GIS) have been successfully used for allocation of spatial clusters that are of interest to explore and determine aetiology of the diseases [11–13], as well as for the study of patterns of spatial and temporal distribution of microbiological plague [14], hypodermatitis [15], foot-and-mouth disease [16] and others.

The work itself was carried out in 2004–2010 and the relationship between animal and human diseases as well as the impact of geographical factors on the epizootic situation were studied.

There is a common belief that the spread of brucellosis is affected largely by economic and geographic factors, *i.e.* factors caused by human activity. At the same time, physical and geographical factors

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(climate, weather) do not have a tangible impact on the disease incidence because animals are being taken care of. The contradiction lies in the fact that particularly the physical and geographical factors can influence the type of agricultural activity, determining the economic efficiency of the stable cattle farming, and pasturing cattle.

Kazakhstan is the second largest country among the former Soviet republics. It is rich with diverse landscapes, from prevailing deserts, semi-deserts, plateaus, and steppes to mountain ranges, and this implies a broad range of environmental conditions. The country has a sharply continental temperate climate, with sharp changes in temperature both during the day and during the year. Such conditions, with a limited number of grazing areas, create a generally unfavorable scenario for the livestock production in Kazakhstan. The global warming observed in recent decades leads to an increase in climate aridisation and thereby to even greater reduction of pasture areas. Despite the above factors, animal husbandry remains one of the priority sectors in the Republic [17]. Livestock disease monitoring is a mandatory function of public services. However, there are no reports on the national situation and the relevant data are not analysed from the perspective of geographical, social and other factors [18]. Among other regions in the world that are relatively well-studied, Kazakhstan remains a “blind spot” and this is despite the fact that Kazakhstan is located at the intersection of important trade routes connecting Asia and Europe [19]. From this perspective, investigating the incidence of brucellosis in Kazakhstan is relevant.

This study aims to determine the national and regional incidence of brucellosis among cattle (cows) and small ruminants (sheep, goats) in the Republic of Kazakhstan, as well as to identify the effect of climatic and geographical factors on the incidence rates.

## 2. Materials and methods

### 2.1. Research design, setting

The diagnostic study was carried out by techniques of classic serology – Rose Bengal test (RBT), agglutination test (AT), complement fixation test (CFT), and enzyme-linked immunosorbent assay (ELISA).

Changes over time in the epizootic situation in terms of brucellosis was analysed, based on presented data and the values of basic epizootic indicators. The risk assessment was based on the number of animals with brucellosis, discovered in a certain area.

### 2.2. Data

Most of the data has been taken from the annual government reports. The procedure for diagnosing brucellosis that was made in fields is standard and does not cause animal suffer.

The research was carried out in the period of 2013–2016 years and consisted the use of graphical and graph-analytic method of investigation.

Brucellosis is a registered epizootic disease in the Republic of Kazakhstan. For this study, part of the data were obtained from the official statistical report of the Committee of Veterinary Supervision and Control of the Ministry of Agriculture. These data contain the absolute numbers of farm animals that positively respond to brucellosis in serological tests for the corresponding period in the regions of Kazakhstan. Also we loaded the table with the number of cattle and small ruminants from the official website of the Statistics Committee of the Ministry of National Economy of the Republic of Kazakhstan (<http://stat.gov.kz/>).

The information used to monitor statistical data was collected by the Laboratory of Microbiology of the Research Institute for Biological Safety Problems during the epidemiological survey of livestock units. This information also includes data on the soil and the comparative characteristics of the surveyed geographic zones, which have a spatial (coordinate) binding.

### 2.3. Methods of clustering

Graphic overlay method was used to detect spatial consistent patterns of spread of the disease and the dependence of the latter on the natural and socio-economic factors [20]. It involved maps creation and comparison of the received images with each other and with other maps previously published. Initial data for the maps were calculated by averaging of the statistics received at different times in order to minimise the impact of climate factors and accidental releases (surges). On the basis of the processed data mapping indices were determined, which will facilitate the identification of these consistent patterns [21].

Graph-analytic method (spatial and temporal analysis) also involves the use of maps, but with smaller units of mapping and data compiled on year. For these maps, you can identify the so-called “hot” point – the separate districts, which can be a source of spread of the disease and “cold spots” that may become the subject of study for disease control. The dynamics of the last enables to evaluate the effectiveness of anti-epizootic measures, namely the presence of regions with increased morbidity that re-emerged after their successful recovery. This method of research will clarify the causes of the spread of animal brucellosis in the Republic of Kazakhstan.

Method of cartograms with graduated colours of quantities in order to display parameters of cartographic representation (mapping) has been selected for several reasons. First reason is that the economic and geographic data are usually summarised according to the administrative division units. Secondly, a significant portion of the available cartographic material also uses administrative divisions. Only the physical and geographical indicators have different units of mapping.

### 2.4. Statistical analysis

The differences between variables were considered significant at  $p \leq 0.05$ . The levels of significance are described separately. To analyse the differences, the following methods were used: the Fisher's two-sample *t*-test for independent samples, the Pearson's correlation coefficients, and the PCA analysis. Statistical calculations were conducted using the Past v. 3.0 software.

Public services that are involved in the brucellosis monitoring system, provided collected information in the form of tables. For its collection and processing, electronic spreadsheet of Libre Office package was used.

The smoothed risk figures of livestock disease were received from the gross cumulative assessments for each period of observation, using empirical Bayes smoothing (EBS). Data processing was performed with use of key figures of accumulated cases of infection in each of the administrative regions in the period from 2013 to 2016.

### 2.5. Spatial analysis

Thematic maps were created in an open geographic information system QGIS version 2.8. In order to identify the natural and socio-economic factors that influence the spread of the disease overlay method was used.

Local cluster analysis was used in order to identify additional causes of the disease. It was performed by using local statistics by I. Moran, a local indicator of spatial autocorrelation (LISA) [29]. As the target variable, there were used cumulative disease incidence rates at the district level. Such space-statistical calculations allow to determine hot spots, as well as the spatial surge, or in this case, the separate districts that are disproportionately different from the global average. GeoDa software package was used to perform these calculations [30].

## 3. Results

Maps of the number of cattle and small ruminants (sheep and goats) compiled by the statistics allow to evaluate the scale of agricultural

**Table 1**  
The Overall Population of Cattle and Brucellosis Incidence in 2011/2016.

Region	Population	No. of Infected Animals	Proportion of Infected Animals, %
Petropavlovsk	Under 150 000	101-1000	0.06-0.19
Atyrau	150 000 – 250 000	101-1000	0.20-0.60
Aktau	150 000 – 250 000	Under 100	0-0.05
Kyzylorda	250 000 -350 000	Under 100	0-0.05
Taraz	250 000 – 350 000	101-1000	0.06-0.19
Kostanay	350 000 – 450 000	2501-5000	0.61-1.00
Kokshetau	350 000 – 450 000	1001-2500	0.20-0.60
Aktobe	350 000 – 450 000	2501-5000	0.61-1.00
Pavlodar	350 000 – 450 000	2501-5000	1.00-1.36
Karaganda	Over 450 000	2501-5000	0.61-1.00
Oskemen	Over 450 000	2501-5000	0.20-0.60
Oral	Over 450 000	Over 5000	1.00-1.36
Taldykorgan	Over 450 000	1001-2500	0.06-0.19
Shymkent	Over 450 000	101-1000	0-0.05

business at the studied area and to assume the existence of natural conditions and economic feasibility for this activity (Table 1).

According to data in Table 1, Petropavlovsk Region lags behind other regions in the respect of cattle production. Among other laggards, the Atyrau and Aktau regions produce 1.5 times more units ( $p \leq 0.05$ ) compared to the Petropavlovsk Region, while the Kyzylorda and Taraz regions do even better than that. The average producers are the Kostanay, Kokshetau, Aktobe, and the Pavlodar regions. The most favourable farming conditions are a characteristic of five regions (i.e., Karaganda, Oskemen, Oral, Taldykorgan, and Shymkent regions). There, cattle production is 3 times higher than in the Petropavlovsk Region ( $p \leq 0.05$ ). Thus, in Kazakhstan, there are nine regions with average and high levels of livestock development, which is almost twice as many as unfavorable regions (5). These data are also put to a graph PCA (Fig. 1).

All effective cattle-producing areas are located on axes with positive values, while unfavorable areas — on axes with negative values.

Findings show the following values of Pearson correlation between (1) the overall population and the number of cases ( $0.68, p \leq 0.005$ ); (2) the overall population and the proportion of infected animals ( $0.46, p \leq 0.10$ ). The maximum value of 0.89 is found for the correlation between the number of infected animals and their proportion,  $p \leq 0.0001$ . Thus, the larger the herd in a given area, the greater likelihood of having brucellosis. These data confirm the overall trend in the sector.

Data on small ruminants are presented in Table 2.

There are two regions with the most developed production of small ruminants (Table 2) and three regions with the average production. The remaining regions produce lower numbers of sheep and goats (Fig. 2).

The values of correlation characterise the connection between (1) the overall population of goats and sheep and the number of animals infected ( $0.56, p \leq 0.03$ ); (2) the proportion of infected animals and the

number of cases ( $0.59, p \leq 0.02$ ); (3) the proportion of infected animals and the number of animals in the total population ( $0.72, p \leq 0.07$ ).

Data processing reveals that Kazakhstan has almost twice as many regions good for cattle breeding as regions that are good for the small ruminants farming.

The correlation variables for cattle and small ruminants are approximately the same. Low variables indicate that high incidence of brucellosis is not necessarily an attribute of areas with the highest population. The incidence rates depend primarily on the preventive practice and on the contribution of the relevant public services.

Comparing these figures with the physical map of the Republic of Kazakhstan (National Atlas of the Republic of Kazakhstan, 2010), we can understand that the farm animal housing of cattle and small ruminants is mostly developed on the hills and plateaus, i.e. in areas where the crop is less developed.

Maps with the number of detected infected animals allow us to estimate the prevalence and spread of the disease by regions of Kazakhstan.

Comparing the maps given on Figs. 1 and 2 (herd of cattle and the number of infected cattle), you can see some correlation. The correlation is more pronounced for small ruminants. This indicates that the method of farming does not show the dependence on the type of animals bred. But in general, the disease incidence of brucellosis in cattle is to some extent opposite to the small ruminants. Geographical factor plays important role in this. Small ruminants are mainly grown in the mountainous and more arid regions, while the cattle – in the highlands. Such conclusion may be reached, when looking at the relief maps and precipitation maps.

The number of infected animals can be affected by the size of herd. With increase in cattle number, the number of infected animals increase. Or conversely, it can decrease, because with the growth of herd it may be given more attention to their health. It is, therefore, advisable to calculate the percentage ratio between the number of infected animals and their total number in the administrative unit by selecting this feature as a cartographic indicator. This option may be most useful in identifying consistent patterns of disease spread.

The same can be said, when having compared data (the number of infected animals and the percentage of their total number). Our data almost completely correlated with the maps of agricultural lands (lands under pasture). In the Republic of Kazakhstan grazing-pasture prevails over the stable cattle farming.

High disease incidence in sheep and goats in the south-western regions is additionally associated with the presence of the border with Kyrgyzstan, which also has a high level of infection among animals. Absence of the checkpoint band at the border, common pastures, and drift ways further increase the disease incidence.

Comparing our data with the data of the number of hectares of pastures per one sheep, you can see the opposite thing: at given number

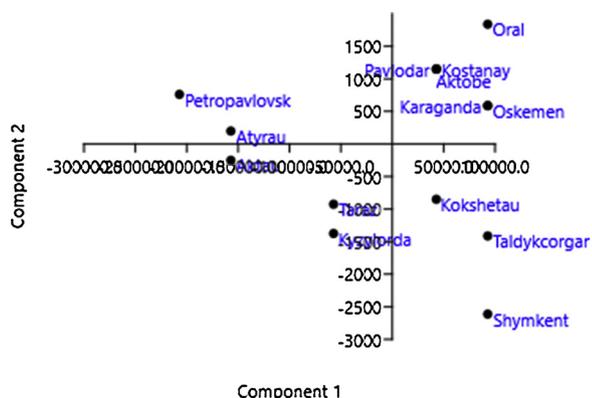


Fig. 1. PCA of economic effectiveness of Kazakhstan regions, case of cattle.

**Table 2**  
The Overall Population of Small Ruminants and Brucellosis Incidence in 2011/2016.

Region	Population	No. of Infected Animals	Proportion of Infected Animals, %
Petropavlovsk	Under 450 000	Under 100	0-0.01
Atyrau	450 000 – 650 000	1001-2000	0.21-0.29
Aktau	Under 450 000	Under 100	0.02-0.09
Kyzylorda	450 000 – 650 000	101-1000	0.02-0.09
Taraz	1 250 000 – 3 000 000	Over 5000	0.21-0.29
Kostanay	Under 450 000	101-1000	0.02-0.09
Kokshetau	450 000 – 650 000	1001-2000	0.30-0.60
Aktobe	650 000 – 1 250 000	2001-5000	0.21-0.29
Pavlodar	450 000 – 650 000	101-1000	0.02-0.09
Karaganda	1 250 000 – 3 000 000	101-1000	0.02-0.09
Oskemen	1 250 000 – 3 000 000	Over 5000	0.30-0.60
Oral	650 000 – 1 250 000	2001-5000	0.10-0.20
Taldykorgan	Over 3 000 000	Over 5000	0.10-0.20
Shymkent	Over 3 000 000	1001-2000	0.02-0.09

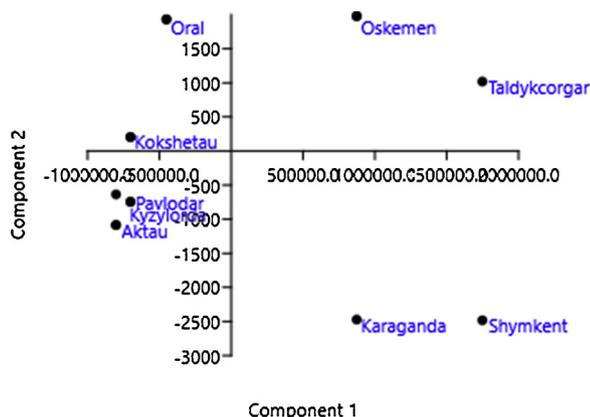


Fig. 2. PCA of economic effectiveness of Kazakhstan regions, case of goats and sheep.

of pastures, the opportunity to catch the disease decreases.

The size of farms, their equipment, and transport accessibility can influence on morbidity too. In addition, important factors in the spread of the disease are sanitation and hygiene, the availability of sufficient water, and a mutual grazing of animals.

To identify the causes of disease, the epizootic situation dynamics was evaluated, which also allows evaluating the effectiveness of anti-brucellosis measures. It would also enable to detect the presence of clusters of disease in time and space. There were areas identified, which belong to one of these spatial clusters:

1) *High-High*: territorial units with the disease incidence higher than the average level, surrounded by areas with the above-average disease incidence level. They correspond to the so-called "hot spots", i.e., the areas with the highest risk of infection.

2) *Low-Low*: areas with below-average disease incidence level, surrounded by areas with below-average morbidity level. They correspond to the so-called "cold spots", i.e. areas with minimal risk of infection;

3) *Low-High*: areas with below-average incidence of disease, surrounded by areas with a higher than average incidence of disease;

4) *High-Low*: areas with a higher than average incidence level, surrounded by areas with below-average levels of morbidity. The third and fourth types are of interest for further study of the mutual influence and existing risk factors;

5) statistically insignificant interaction: the areas where the disease incidence is not related with that one in neighbouring areas.

As it can be seen from Fig. 3 and 4 and Table 3, it) holds steady at the level of indicator of the «High-High» type in Ereimentau district, in the Akmola region for four years (2013–2016), while Korgalzhyn district at the last year of three-year period showed the best indicator type of «High-Low». Significant changes occurring in the indicator type of

«High-Low» were observed in Akkol, Yenbekshilder, and Tselinograd districts and in Stepnogorsk, but these districts showed bigger incidence of the disease in sheep and goats at the end of the three-year period and raised up from the indicator of «Low-Low» to «High-Low», which can be associated with transmission of the infection. In general, cattle indicators showed a positive trend that cannot be said about the small ruminants, where the indicator «Low-Low» dropped from 16 to 12 districts in three years.

A marked increase in the incidence of the disease in cattle was registered in Karaganda region. In 2013, in terms of «High-High» indicator, it was marked only in Karkaraly District, while in 2014 and 2016 it was joined by Buharzhayrau and Abay districts, which were ranged in terms of type indicators of «Low-High» and «Low-Low», respectively. Also Karkaraly District has risen to a value of «High-High» from «Low-Low» in 2016 by the sheep and goats, which also indicates the transmission of the disease to farm animals. Despite this, the disease incidence indicators referred to the small ruminants remain consistently favourable for three years. The reason for this may be non-compliance with sanitation, leading to the emergence of brucellosis in the farms that already passed through sanitation.

Atyrau is the main "epicenter" of cattle infection. In Atyrau no improvement has been seen over three years, moreover, the infection has spread in the nearest southeastern districts of Kyzylkoginsky and Makat. This situation has worsened from «Low-Low» and «Low-High» to «High-High», respectively. Spread of the disease among small ruminants has a similar picture, but differs in that the infection has been eradicated in Atyrau and Makat district during three years and has remained at a high level in Kyzylkoga district.

In Zhambyl region the situation remains stable. In this region Baizak, Kordai, Sarysu, and Zhambyl regions have been kept to the level of indicator of «Low-High» type for four years and did not show positive developments.

During the period of monitoring, South-Kazakhstan region mainly demonstrated a good indicator of «Low-Low» over the majority of the territory while negative dynamics in Lenger district for cattle and small ruminants were recorded only in 2016 to «Low-High».

A similar pattern picture as in South Kazakhstan region was observed in Kyzylorda region. In 2014–2016, the spread of the disease was found at the level of «Low-High» in the region of Zhalagash and in Kyzylorda. In Almaty region, despite the favourable conditions for cattle, Karatalsky district was found at the level of «High-Low» and 10 regions (Issyk, Ili, Karasai, Koku, Sarkansky, Alakol, Raiymbek, Kerbulak, Enbekshikazakh, and Uygur) have been determined at the level of «High-Low» in 2016. The number of districts increased from 1 to 6 by the indicator type of «Low-High». In general, the number of regions in the category of «Low-Low» decreased from 20 to 10 for the period 2013–2016. What potentially can be associated with an increase in the spread of infection among sheep and goats in 2013, where the indicator

of «High-High» increased from 0 to 1, «High-Low» from 0 to 3, and «Low-High» from 0 to 2.

In the North-Kazakhstan region, the situation remained without changes throughout the whole monitoring period: M. Zhumabaev district is kept at «High-Low» level and Akzhar and Akkayin districts stay at the level of «Low-High».

In Pavlodar region there is an increase in disease incidence in small ruminants. So in 2013, the level of «High-High» was recorded in Bayanaul district and in of Ekibastuz, while in 2014, this indicator comprised seven regions.

In Kostanai region all territory belonged to «Low-Low», and in 2014 this indicator comprised 5 out of 20 available districts. The disease incidence at the level of «High-High» was found in areas Zhangelinskoy and Karasu in 2014 and 2015, and in Ualianskoy in 2016. When indicator of «Low-Low» among small ruminants lowered from 20 to 14 for the entire monitoring period. Karasu district remained unfavourable for cattle and small ruminants in 2015.

Spatial clusters, that represent the epizootic process, are in North-Kazakhstan region ( $P = 0.001$ ) for small ruminants and in West Kazakhstan region ( $P = 0.001$ ) for cattle. Analysis of epidemic situation of animal brucellosis in the scale of regions shows that only Mangistau region is free of the disease. North-Kazakhstan region is assigned to class *Low-Low* (districts with the disease incidence at lower-middle level, surrounded by areas with the disease incidence at the level below average). They correspond to the so-called "cold spots", i.e. areas with minimal risk for brucellosis cattle infection.

Areas with the disease incidence of lower-middle, surrounded by areas with a higher than average disease incidence have been referred to class *Low-High*. There have been attributed only two regions: Kyzylorda and Zhambyl. They are of interest for further study of the mutual influence and existing risk factors. All the other 10 regions, out of which 17 districts have the status of *High-High* class. They are territorial units (in this case districts) with a disease incidence higher than the average level and surrounded by areas with a disease incidence level above the average, corresponding to the so-called "hot spots", i.e. territories with the highest risk of infection).

#### 4. Discussion

The disease is spread in such countries as China [22], Iran [23], Mexico [24], Pakistan [25], France, Canada, Australia, Italy, and Spain [31–33]. Australia, New Zealand, and Israel [34] have declared that they managed to eliminate brucellosis in their territory. This process was also completed in the USA [35,36]. However, *B. abortus* continues to circulate among wildlife in the Yellowstone National Park [37]. Brucellosis is most common in the Near East, Central Asia, and the Persian Gulf, central part of South America (especially in Peru), India, and Africa [38–43].

Clinical manifestations of the disease in humans are still common in the Near East, Asia, Africa, central part of South America, Mediterranean countries, and the Caribbean Sea basin. At the same time, brucellosis is rarely encountered in most developed countries due to systematic screening and livestock vaccination programmes [28].

In Kyrgyzstan, the rate of brucellosis in humans increased from 1997 to 2002 by almost two times (from 20 to 36 cases per 100,000 persons). In the Batken Region, up to 68 cases per 100,000 persons were registered [44].

The economic losses of milk and meat output caused by brucellosis are 20% and 15%, respectively. The main cause of brucellosis in humans in Turkey is the consumption of raw milk and dairy products (especially soft cheese) made of milk from infected animals [42]. The same is true for India [43]. In Kuwait, infection by inhalation was registered among people who set up camps in deserts during the lambing season [45].

Brucellosis is common in India due to intensive development of agriculture and noncompliance with veterinary and sanitary rules, in

particular, the use of sperm for insemination of unexamined animals, insufficient hygiene of management, and uncontrolled movement of infected animals [18].

The global climate change, namely the overall warming, contributes to the increase in the incidence of brucellosis in animals and humans. Such data were obtained for Mexico, Brazil, Canada, Venezuela, Peru, and for many Asian countries [23–25].

To summarize the foregoing, brucellosis remains an insufficiently studied disease in Latin and Central America and in most Asian countries. Its true scale is unknown and transmission pathways remain in question. Kazakhstan is no exception. This study shows that depending on geographical factors (landscape, which defines the pasture boundaries) there is a correlation between the incidence of brucellosis and the overall population number. This connection can be found in the case of both small ruminants and cattle. In Kazakhstan, there are nine regions producing high numbers of cattle heads and five regions with high production of small ruminants. In the light of the present data, the provinces that are the most favourable for the livestock farming are most susceptible to brucellosis [26,27]. Thus, the constant monitoring of brucellosis is needed not only in Kazakhstan but also in the neighbouring countries.

In addition to the threat that brucellosis poses to agricultural and wild animals, there is also a threat posed to human health. Social factors that can significantly affect the incidence of brucellosis among humans were highlighted in previous studies and Kazakhstan can be found in the list of countries at risk.

The economic standard of living, at which people are forced to keep farm animals in the individual farms has not been considered in most studies. The same can be said about the constrained differentiation of grazing, namely housing of several species of animals, which leads to shared grazing. The relatively low level of participation of Central Asian countries in the global division of labour leads to increased unemployment among the local population, and this means that there is a large proportion of small private farms with low level of equipment and in which sanitary rules are not applied. The additional negative effect derives from the unguarded border and a high level of infection of animals in neighbouring countries.

At the same time, both domestic and foreign authors correctly identify the main causes of the spread of brucellosis: improper farming and gaps in epizootic monitoring system. Apparently, the way to a quick solution to the problem of brucellosis lies in the change of land use system, namely by assigning of certain lands to individual farms. This will minimise the amount of contact between herds of different farms and prevent reinfection in farms that already passed through sanitation.

Modern requirements to veterinary and epizootic service include not only the identification, fixation, and complex of measures to reduce the spread of disease, but also the definition of predicted patterns of mass diseases, identifying the risk factors that caused epizootic problem [10]. Also, in collaboration with other professionals, it was carried out the development of system for monitoring and support of management decisions aiming at the prevention of diseases, their localisation in case of occurrence, and total elimination in the region or globally in the future.

At present, there is no doubt about the fact that the organisation of preventive and anti-epizootic measures should be carried out with the use of information and communication technologies. The use of technologies will facilitate a number of operations. For example, researchers will be able to determine the exact border of unfavourable localities, visualise them with the drawing of epizootic significant objects, followed by further zoning and clustering of administrative territories by the degree of prosperity and spatio-temporal analysis.

In the frames of the study there were carried out an analysis and assessment of the reliability of the official statistical reports on brucellosis of animals (cattle and small ruminants) in Kazakhstan for the period from 2013 to 2016. The obtained data were visualised by using

the geographic information system (GIS), which resulted in creation of a series of thematic maps. The latter greatly simplified the analysis of the spatial distribution of brucellosis among the animals and identification of causes of the infection spread. Thus, the influence of climatic and geographical factors on the incidence of brucellosis is, most likely, mediated due to their influence on human economic activity. The combined effects of natural conditions and animal welfare can contribute to the rooting of brucellosis in a particular area.

In the following study, brucellosis in animals will be investigated with the help of graphics and graphical-analytical methods. It is proposed to map the farms, where cases of brucellosis were diagnosed with the gradation of the graphical symbols referred to the size of farms and the number of infected animals. This method of mapping is also called geocoding. This makes it possible to observe the dependence of the disease from the infrastructure (railways), the location of farms themselves, their size, and other characteristics. In the future, GIS will become a convenient tool for epizootic monitoring ensuring the proper construction of anti-epizootic measures and their rapid adjustment.

The use of spatial autocorrelation proved to be a great benefit for better visualisation of the endemic, especially in elucidating the actual distribution of brucellosis cases in the regions (districts), and providing an effective tool for planning the monitoring of the disease at a local level.

#### Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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