Spatial and Temporal Distribution Changes of Human Brucellosis in Inner Mongolia, China, effects of Husbandry and Control Measures

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Abstract

Background

Inner Mongolia has the highest incidence rate, causing great public health and economic losses. A number of policies to guide the prevention and control of human brucellosis had been issued and have made some achievements. Analysis of the distribution characteristics and changes of human brucellosis is important for the targeted prevention and control of this disease.

Methods

We collected various policies and measures related to brucellosis promulgated, and comprehensively analyzed the spatial and temporal distribution of human brucellosis in Inner Mongolia from 2005 to 2019 using the Bayesian theory of space-time modeling.

Results

With the implementation of various policies and measures, great achievements have been made and distribution trends changed. Some western regions have changed into stable or cold-spot counties, and most cities in the eastern region have become hot-spot counties during the time period. The rising trend of risk in three cities is slowing down, while the risk in two cities is growing faster than the overall trend.

Conclusion

The effective prevention and control measures are essential. The analysis results of this study may provide a theoretical and scientific basis for the public health department to

34 develop targeted effective prevention and control measures for human brucellosis.

35 **Keywords:** brucellosis; spatial trend; time trend.

Introduction

Human brucellosis is a zoonosis caused by *Brucella*, which has a serious impact on human health and social economy(1, 2). Its clinical manifestations include fever, fatigue, sweating, arthritis and so on(3, 4). Brucellosis is easy to be misdiagnosed as a common cold and other diseases. Human brucellosis is usually transmitted directly or indirectly by diseased animals(5, 6). Farmers, herdsmen, slaughterhouses and veterinary workers are high-risk groups(7). Since 1995, the incidence of human brucellosis in China has gradually increased. In 2001, it has spread to more than 10 provinces in China, and by 2013, it has become prevalent in 25 of 32 provinces in China.(8, 9). Developments of Economics, transportation and animal husbandry lead to the increased risk of human infection with *Brucella*. Human brucellosis is prevalent in the north China and is gradually transferring from north pastoral areas to south grassland and agricultural areas.

Inner Mongolia is an important pastoral area in China, its animal husbandry is developed, and the incidence of human brucellosis has been increasing. Since 2004, China has included brucellosis in major animal disease surveillance plans, and has carried out national human brucellosis surveillance(10). On this basis, Inner Mongolia, which has the highest incidence, has also taken measures such as agricultural insurance premium subsidies and the establishment of a training course

for human brucellosis control projects in order to strengthen the prevention and treatment of human brucellosis. The incidence of human brucellosis from 2011 to 2016 accounts for about 40% of the country(11, 12). A recent study found an average of 3.79% anti-Brucella positive in Inner Mongolia, and seroprevalence of human brucellosis increased gradually, but the incidence of human brucellosis decreased(13).

Transmission of brucellosis from animal and humans, and spatiotemporal distribution are important for control of this disease. At present, several studies investigated the transmission of *Brucella* with mathematical models. Hou et al. proposed a dynamic model of transmission of *Brucella* from sheep to human to analyze the transmission of *Brucella* in Inner Mongolia(14). Li et al. analyzed the trend of future human brucellosis cases by establishing a dynamic model describing the transmission from sheep and sheep to human (15). These studies used different mathematic models. Compared with other models, Bayesian model is a statistical prediction models with unique advantages. In this paper, we use Bayesian model to analyze the data of reported cases, to obtain the dynamic change trend of disease with time, which is conducive to the development of prevention and control plan for brucellosis.

Methods

The study area

Inner Mongolia Autonomous Region (37 ° 24 ′ - 53 ° 23 ′ N, 97 ° 12 ′ - 126 ° 04 ′ E) is located in the north of China. It borders Heilongjiang, Jilin, Liaoning and Hebei in the East, Shanxi, Shaanxi and Ningxia in the south, Gansu in the southwest, Russia and Mongolia in the north. The whole province is a high prototype geomorphic area, covering hills, plains, mountains, deserts, lakes and other landforms, with a temperate continental climate. Inner Mongolia belongs to arid, semi-arid and cold semi humid climate areas. The annual average temperature in Inner Mongolia is - 3.7 ℃ - 11.2 ℃, and the annual average precipitation is 392mm (http://data.cma.cn/site/index.html). By the end of 2019, the resident population will be 25.396 million, with an urbanization rate of 63.4%. Agriculture and animal husbandry are main industries of the province.

Data collection

Human brucellosis cases in Inner Mongolia from 2005 to 2019 were collected through the National Notifiable Disease Surveillance System (NNDSS). Human brucellosis was diagnosed through a combination of epidemiological exposure (contact history of *Brucella* or living in endemic areas) and clinical manifestations and confirmed by positive results of presumptive laboratory tests(16, 17). After cleaning and correcting errors, the data were entered into Excel datasheets. Human

brucellosis incidence per 100,000 was calculated. The number of cattle and sheep from 2005 to 2019 was acquired from national bureau of statistics (http://www.stats.gov.cn/tjsj/ndsj/). The published documents on the prevention and control measures of brucellosis were obtained from the official websites of the National Health Commission of the People's Republic of China and the Health Commission of Inner Mongolia Autonomous Region.

ArcGIS analysis

The most recently updated electronic map of Inner Mongolia was used for ArcGIS analysis and linked to Excel. The risk changes of human brucellosis in Inner Mongolia were analyzed by Bayesian spatiotemporal model, and the analysis results were shown by using color changes in polygon layers. Since the address of the case information does not include township information from 2016, the case information from 2005 to 2015 is analyzed at the township level, and the case information from 2005 to 2019 is also analyzed at the district level.

The model

The specific model is divided into three parts. The first part is the data model, which is the statistical data of low incidence, assuming that the parameters n_i and μ_{it} obey the Poisson distribution: $y_{it} \sim Poiss(n_i \mu_{it})$, where i is the region, t is the time, y is the number of cases, n is the number of people at risk, μ is the risk of disease, and

it is assumed that the number of people in each township did not change during the study period;

The second part is the process model. The logarithmic transformation of μ_{it} to the disease risk allows the relative risk to be expressed as a linear combination of the spatial, temporal, and spatiotemporal interaction components. The mathematical expression is $\log(\mu_{it}) = \alpha + s_i + (b_0 t^* + v_t) + b_{li} t^* + \varepsilon_{it}$, where α is the fixed effect of the overall relative risk, s_i describes the risk difference between the disease risk in the area during the observation period and the risk in the entire study area, and $b_0 t^* + v_t$ describes the disease risk in the entire study area relative to the overall change trend of the mid-year observation year, where b_0 represents the time trend of the study area, t^* is the time span relative to the intermediate time point, $b_{li} t^*$ allows each town to have a different time change trend, and ε_{it} is used to explain local changes that it cannot be explained by spatiotemporal random effects;

The third part is the parametric model. According to the Besag-York and Molliè (BYM) model, the spatial structure effect is defined by the prior conditional autoregressive (CAR) structure(18). In this process, a spatial adjacency matrix and a temporal adjacency matrix are defined. The over-discrete parameter ε obeys the normal distribution, with an average value is 0, and the variance is ${\sigma^2}_\varepsilon$. It is generally assumed that the variance of each parameter obeys Gamma (a, b) (19). By calculating the spatial relative risk probability, the probability that exp (s_i) is greater than 1 is

divided into three categories: areas with probability> 0.6, 0.4 ~ 0.6, and <0.4 are defined as hot-spot counties, stable counties, and cold-spot counties, respectively. Similarly, by calculating the relative change in time, the probability of exp (b_{li}) greater than 1 is divided into 3 categories: the counties with the incidence probability greater than 0.6 are considered to have a faster risk trend than the overall trend; between 0.4 and 0.6 were considered to have the same risk trend as the overall trend; and less than 0.4 are considered to have a slower risk trend than the overall trend .

Results

The collected case data were collated by excluding duplicate data and cases with incomplete information. During the time period of 2005-2019, the number of human brucellosis cases in Inner Mongolia is the largest, accounting for 29% of total number in China, is more than twice that of the second (Fig. 1). The male patients account for 70.03% (112038/159973) of the total cases, 2.3 times that of females, and the incidence was highest among those aged 35-54 (Table 1). More cases occurred in June and July, followed by May, April, August, and March, which were mainly spring (March to May) and summer (June to August). 10.03% (16058/159973) of the cases were corrected cases in the reporting system, indicating that the misdiagnosis was quite common. In addition, among these cases, there were 109,196 (68.28%) farmers,

149 31,933 (19.97%) herders, 663(0.41%) service staff, 2,482(1.55%) students, and
150 634(0.40%) medical staff.

151 Since 2004, China has included the detection of brucellosis in the annual major
152 animal epidemic detection plan, and launched the national human brucellosis
153 detection work (Table 2). In 2005, the cooperation mechanism for the prevention and
154 control of zoonotic diseases was established and new version of “National Human
155 Brucellosis Detection Program” was issued. In 2007, the “Technical Specifications for
156 the Prevention and Treatment of Brucellosis” was revised and the subsidy measures
157 for brucellosis were implemented in Inner Mongolia Autonomous Region. Since then,
158 Inner Mongolia has also opened technical training courses for human brucellosis
159 prevention and control projects, implemented the "Heilongjiang Province and
160 Northeast Inner Mongolia Border Area Development and Opening Plan", issued a
161 new training program for professional farmers and herdsmen and practical talents in
162 rural pastoral areas, and formulated the "National Brucellosis Control Plan (2016-
163 2020)" and other planning measures. Human brucellosis has also received increasing
164 attention, and the government has promulgated corresponding prevention and control
165 policies.

166 Since 2005, the number of cattle and sheep in Inner Mongolia fluctuated and
167 increased, while the number of human brucellosis cases began to increase from 2006,
168 fluctuated and declined after the peak in 2011(Fig. 2A, B and C). The number of

human cases was positively correlated with the number of cattle in stock (Fig. 2D). The number of cases decreased as the number of sheep increased, indicating a negative correlation of human cases with sheep number (Fig. 2E).

The Bayesian model was processed using the WinBUGS software. The model processed two chains. After a total of 20,000 iterations, the model tended to converge. After the model converged, it iterated 10,000 times for parameter estimation. The convergence of the model was determined by the Gelman-Rubin statistic. The convergence of the model was judged by comparing the variance between the chains and the variance within the chains (Fig. 3A and B). The overall temporal change trend in the model estimation results is calculated from the model (exp $(b_0 t^* + \upsilon_t)$), and describes the change over time of the risk of human brucellosis. From 2005 to 2015, the parameter of the average time trend coefficient b_0 of human brucellosis in the towns of Inner Mongolia was estimated to be 0.1349, that is, the disease risk in the following year was about 1.144 times the disease risk in the previous year. The risk of incidence in the towns of Inner Mongolia showed a downward trend from 2005 to 2011, but it started to increase in 2012 and only slightly decreased in 2013(Fig. 3C). From 2005 to 2019, the parameter of the average time trend coefficient b_0 of human brucellosis in the counties of Inner Mongolia is estimated to be 0.006, that is, the disease risk in the following year is approximately 1.006 times the disease risk in the previous year. The risk of incidence in the counties of Inner Mongolia increased from

2005 to 2010, began to decline after 2011, and increased slightly in 2019(Fig. 3D). Generally, the risk trend in Inner Mongolia was slightly rising.

The cases with detailed addresses from 2005 to 2015 were matched with the map. The areas with higher incidence were mostly distributed in Xilinguole League, Xing'an League, Baotou City, Ulanqab City, and Hulunbuir City (Fig. 4A). Xilinguole League, Wulanchabu City, Hohhot City, and Baotou City, located in the central region of Inner Mongolia, were hot-spot counties (Fig. 4B). The risk trend of Chifeng, Tongliao and Xing'an League increased faster than the overall trend, while that of Ulanchab, Hohhot, Alxa League and Baotou, Ordos and Bayannur increased slower than the overall trend (Fig. 4C).

The 2005-2019 cases were analyzed and matched to the district-level map. It was found that the eastern cities of Inner Mongolia, Xing'an League, Tongliao, Hulunbeier, and Chifeng, had a higher incidence (Fig. 5A). In addition, the incidence was higher in the two districts of Bayannaoer. The spatial analysis found that 40 districts in Hulunbuir City, Xing'an League, Tongliao City, Chifeng City and Xilinguole League in northeastern Inner Mongolia were hot-spot counties, and other areas were stable or cold spot counties (Fig. 5B). A total of 11 districts in Bayannaoer City, Ordos City and Chifeng City had a higher risk trend than the overall trend, and the risk trends in other regions were consistent with the overall trend or slower than the overall trend. Among the districts and counties where the risk trend of the disease

was higher than the overall trend, only Hongshan District was a hot-spot county, nine districts were cold-spot counties, and one district was a stable county (Fig. 5C).

Discussion

Brucellosis was firstly reported in China in 1950's. With nationwide efforts, the incidence was reduced to a very low level. However, since the mid-1990s, human brucellosis has re-emerged in China. The incidence of human brucellosis in Inner Mongolia is the highest one and much higher than that in other provinces(20). This is consistent with the fact that Inner Mongolia has the highest livestock production in China. Brucellosis is mainly transmitted to humans indirectly or directly through diseased animals, and has strong profession relevance. Therefore, Inner Mongolia is the main epidemic area of human brucellosis in China, which is closely related to its developed animal husbandry. This study conducted demographic, seasonal, and spatial-temporal analysis of human brucellosis cases from 2005 to 2019, providing a scientific basis for the prevention and treatment of brucellosis.

By analyzing the characteristics of human brucellosis cases, it is found farmer is the main occupation for human brucellosis cases, while herder ranks the second, which is consistent with other reports(21). Farmers use the same living space with livestock, make it easy to contact sick animals. Lower awareness of the transmission of *Brucella* by livestock, also make the farmers more likely to be infected with

228 *Brucella*(22). The incidence of herdsmen and livestock-related workers is high,
229 because they are often exposed to livestock. However, the diseased animals are not
230 quarantined, so the incidence is relatively high. This study found that human
231 brucellosis is more common in men and can occur at any age, with most cases
232 occurring between 35 and 54 years of age. In addition, human brucellosis has obvious
233 seasonality, and it occurs frequently in spring and summer. This is related to many
234 factors; one of which is that young and old men are the main labor force in China.
235 Inner Mongolia is dominated by agriculture and animal husbandry, which are related
236 to seasonal factors, such as breeding operation, precipitation, animal movement,
237 sunshine level and wind speed(23). In spring, the temperature increases, which is
238 suitable for bacterial reproduction, and animals start to move, which increases the risk
239 of animal infection. With the change of temperature and time, shearing wool and
240 animal delivery increase the possibility of human infection by contacting the diseased
241 animal(24). In addition, the increase of meat demand in summer, a large number of
242 livestock slaughtering also increased the risk of disease of the workers engaged in
243 slaughtering(25). Several reasons make human brucellosis diagnosis difficult: the
244 clinical symptoms of human brucellosis are not typical and often ignored by patients;
245 the patients live in remote areas where the medical level is insufficient or unreachable,
246 and the medical staff's awareness of this disease is not strong. It can be seen that

insufficient quarantine of livestock and inadequate awareness of brucellosis in high-risk groups will lead to high incidence of human brucellosis.

China's animal husbandry continues to develop, and Inner Mongolia is an important pastoral area with a high incidence of human brucellosis. The number of cases in Inner Mongolia began to increase in 2005 and peaked in 2011.Since 2004, China has incorporated the detection of brucellosis into the annual major animal epidemic detection plan and carried out the national detection of human brucellosis. Increasing animal husbandry and aquaculture, as well as the high incidence of human brucellosis, are attracting increasing attention. The cooperation mechanism of zoonosis prevention and treatment and National Human Brucellosis Detection Program was established in 2005. Subsequently, workshops on brucellosis control were held in major provinces and cows eliminated due to brucellosis were included in the subsidy. In addition, the “Technical Specifications for the Prevention and Control of Brucellosis”, “Brucellosis Control Manual” and “Emergency Plan for Major Animal Epidemics in the Autonomous Region” were revised. Therefore, the prevention and treatment measures for brucellosis have been gradually improved. From 2005 to 2008, the overall incidence of brucellosis among Inner Mongolians increased, but only 33.33% (4/12) cities increased each year. It can be seen that preventive and control measures taken before 2008 got some achievement, but the transmission of brucellosis cannot be completely controlled.

267 Brucellosis is a natural epidemic disease, which exists latent in nature for a long
268 time, the epidemic spot has not been thoroughly purified, the infectious source can't
269 be effectively eradicated, and the feeding and management methods are backward,
270 and the awareness of public protection is weak. These may be the reasons why the
271 incidence of human brucellosis is still increasing despite the implementation of
272 prevention and control measures. In 2009, the number of cattle and sheep farming
273 increased again. Inner Mongolia began to ban dairy cows from being infected with
274 brucellosis milking and quarantine of livestock, which were diagnosed and
275 slaughtered on a large scale. On this basis, propaganda and education activities such
276 as technical training courses on the prevention and control of human brucellosis were
277 also held to improve the understanding of brucellosis and reduce the possibility of
278 human brucellosis infection(26). The route of human brucellosis infection has been
279 gradually understood and sheep have been vaccinated twice a year. Although the
280 vaccination rate of sheep reached 31.6%, it could not completely prevent the
281 transmission of *brucella* to humans. Besides, adequate control measures were not
282 taken for cattle. Therefore, human brucellosis has a negatively correlated with sheep
283 number and a positively correlated with cattle number (10).

284 The incidence of human brucellosis decreased after 2011, which shows that the
285 prevention and treatment of brucellosis has achieved certain results. However,
286 policies such as "National Plan for the Prevention and Control of Animal Epidemies

(2011-2020)” should be effectively implemented and measures should be taken to further consolidate it. At the same time, problems need to be found and corrected in time. For example, in 2016, it was found that there were problems such as non-standard diagnosis and treatment, overtreatment and so on. Inner Mongolia decided to abolish such documents as the "Brucellosis Diagnosis and Treatment Program for Human in Inner Mongolia Autonomous Region (Trial)". Effective prevention and control measures play a vital role in the prevention and control of human brucellosis. On this basis, it is also necessary to increase the publicity and standardize the animal quarantine supervision system.

The incidence of Baotou City, Hohhot City and Ulanchab City is high, these cities changed from hot-spot counties to stable counties. Prevention measures, such as free treatment of patients with brucellosis and increased publicity, were carried out.(27). These areas should continue active prevention and control and further consolidate the prevention and control of human brucellosis. The northeast of Xilingol League in Inner Mongolia has been hot-spot counties, and the northern and eastern parts of Inner Mongolia have become hot-spot counties. The geographical and climatic conditions of Xilingol League are suitable for livestock breeding, its high-quality natural grassland area reaches 180,000 km^2, with a total population of 1.04 million and the pastoral population accounts for 54.6%(56.8/104.05) (28). In 2019, the number of livestock (big livestock and sheep) in Xilingol League was 13.334

307 million, compared with 67.806 million in Inner Mongolia, which was 19.7% of the
308 whole province (http://tjj.xlgl.gov.cn/ywlm/tjsj/lnsj/sczz/). The number of livestock
309 raising and the number of people engaged in animal husbandry industry in this area
310 are large, and the suitable climate can lead to long-term survival of *Brucella*, and the
311 possibility of human infection with *Brucella* is high. At present, human brucellosis
312 has gradually spread from animal husbandry to towns. The continuous development
313 of animal husbandry and free grazing across regions have increased the probability of
314 brucellosis epidemic(29, 30).In addition, the central and eastern region of Inner
315 Mongolia borders Heilongjiang, Jilin and Liaoning, where the incidence is also high.
316 Private livestock trading will lead to the circulation of sick animals and increase the
317 risk of *Brucella* infection(31). For these hot counties, the relevant government
318 departments in these areas still need to strengthen animal husbandry and quarantine,
319 strictly implement immunization policies and the culling of diseased animals, and
320 improve the prevention and control awareness of relevant personnel to reduce the
321 incidence of human brucellosis. In addition, for the counties adjacent to high
322 incidence areas, relevant departments should strengthen the implementation of
323 epidemic prevention measures, strictly quarantine circulated livestock, and take
324 corresponding measures to contain private livestock transactions.

325 It is found that effective measures can not only stabilize the incidence of human
326 brucellosis in this area or turn it into a cold-spot area, but also reduce the risk of

disease. Tongliao City has a large grassland area, mainly farming cattle and sheep, and the inhabitants are mainly Mongolians. Animal husbandry is their main source of income. The educational level of the inhabitants is mostly primary school or below, the proportion of those engaged in semi-agricultural and semi-herdsmen is 52.65%, and the awareness of the disease is low, so the disease risk in this area is higher(32). Therefore, it is necessary to strengthen the knowledge popularization of the high-risk population in this area, implement the quarantine work of livestock, kill the sick livestock in time and make follow-up compensation. Like Bayannuer City and Ordos City, these areas have changed from stable areas to cold-spot areas. The western region of Inner Mongolia is considered as a non-epidemic area, but Ordos and Bayannuer are important animal husbandry bases and historical epidemic areas of brucellosis(33, 34). The epidemic prevention measures have reached the standard of stable control, so they turned into cold-spot areas. However, no positive measures have been taken to further consolidate the area. With the economic development, the flow of livestock is huge, the cycle is short, and the detection of livestock is not strict. In addition, the lack of timely elimination and killing of sick animals, insufficient knowledge of the disease among high-risk groups and imperfect protective measures lead to an increased risk of disease in the region. (35). Therefore, although prevention and control measures can control the prevalence of human brucellosis, all regions should supplement and adjust the prevention and control measures according to local

characteristics. These areas should continue to carry out quarantine and cull diseased animals, improve quarantine measures according to local livestock circulation, and increase publicity to high-risk groups.

Like Linxi County, Bahrain Right Banner and other areas are the epidemic areas of Chifeng City, the incidence of which accounts for 61.31% of Chifeng City, but it is gradually decreasing.However, the incidence in Ningcheng County and Hongshan District has been relatively low and the risk of disease is high.(36). In the northern region of Chifeng, the grassland area is large, and the proportion of farmers and herdsmen is high. Due to the urbanization, increased population mobility and the expansion of the meat market have led to an increased incidence in the southern regions. Relevant departments in high-incidence areas have taken effective prevention and control measures, so the incidence growth is slower than the whole. However, the incidence in Ningcheng County and Hongshan District has been relatively low, and the awareness of human brucellosis and related measures in this area are insufficient, so the risk trend increased faster than the whole. Therefore, the relevant departments should pay attention to the prevention and control work in all regions, regardless of the incidence rate of the area, and take timely preventive measures through the analysis and prediction of the existing data.

In conclusion, Inner Mongolia has developed agriculture and animal husbandry, and the incidence of human brucellosis is the highest in China. The risk of human

brucellosis in the whole Inner Mongolia is slightly increasing. China and the Inner Mongolia have issued several documents to prevent and control human brucellosis. The implementation of the measures has achieved certain results, which has reduced the incidence of human brucella in Inner Mongolia, and some areas turned into stable or cold-spot areas or reduced the risk of disease. However, parts of the Middle East and Midwest are still hot-spot areas, and there are areas with higher risk of disease in the autonomous region. Effective prevention and control measures are indispensable. On this basis, it is still necessary to improve prevention and control measures based on the actual situation of various regions, such as increasing publicity, strict quarantine on circulating livestock and complete vaccination of livestock. In addition, areas where human brucellosis has been controlled still need to take further measures to consolidate.

Ethics approval and consent to participate

The authors confirm that the ethical policies of the journal, as noted on the journal's author guidelines page, have been adhered to and the appropriate ethical review committee approval has been received.

Consent for publication

Not applicable.

Availability of data and materials

The data that support the findings of this study are available from the National Notifiable Disease Surveillance System, but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available. Data are however available from the authors upon reasonable request and with permission of the Plague and Brucellosis Prevention and Control Base.

Competing interests

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Author Contributions

Z. Chen, L. Song and D. Wang conceived and designed the study, Q. Zhang, Y. Wang and J. Zhai participated in data collection and analysis, Qi Zhang and Z. Chen draft and revised the manuscript.

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Figures

Fig 1. Analysis of human brucellosis in China. (A) The number of cases in different provinces; (B) Proportion of cases in different provinces.

Fig 2. Agricultural data and the number of cases from 2006 to 2016. (A) The number of cattle in stock (10,000 heads). (B) The number of sheep in stock (10,000 heads). (C)The number of human brucellosis cases. (D) The correlation between human case and cattle number. (D) The correlation between human case and sheep number.

Fig 3. Bayesian model analysis results. (A) the variance of spatially variable components (${\sigma_s}^2$) and the variance of time-variant components (${\sigma_{b1}}^2$) of Inner Mongolia from 2005 to 2015. (B) the variance of spatially variable components (${\sigma_s}^2$) and the variance of time-variant components (${\sigma_{b1}}^2$) of Inner Mongolia from 2005 to 2019. (C) The time relative risk from 2005 to 2015. (D) The time relative risk from 2005 to 2019.

Fig 4. Spatial analysis of human brucellosis from 2005 to 2015 at county level. (A) Distribution of human brucellosis incidence. (B) The cold spots and hot spots of human brucellosis in Inner Mongolia. (C) The trend of risk changes in Inner Mongolia.

Fig 5. Spatial analysis of human brucellosis from 2005 to 2019 at city level. (A) Distribution of human brucellosis incidence. (B) The cold spots and hot spots of risk in Inner Mongolia. (C) The trend of risk changes in Inner Mongolia.

Figures

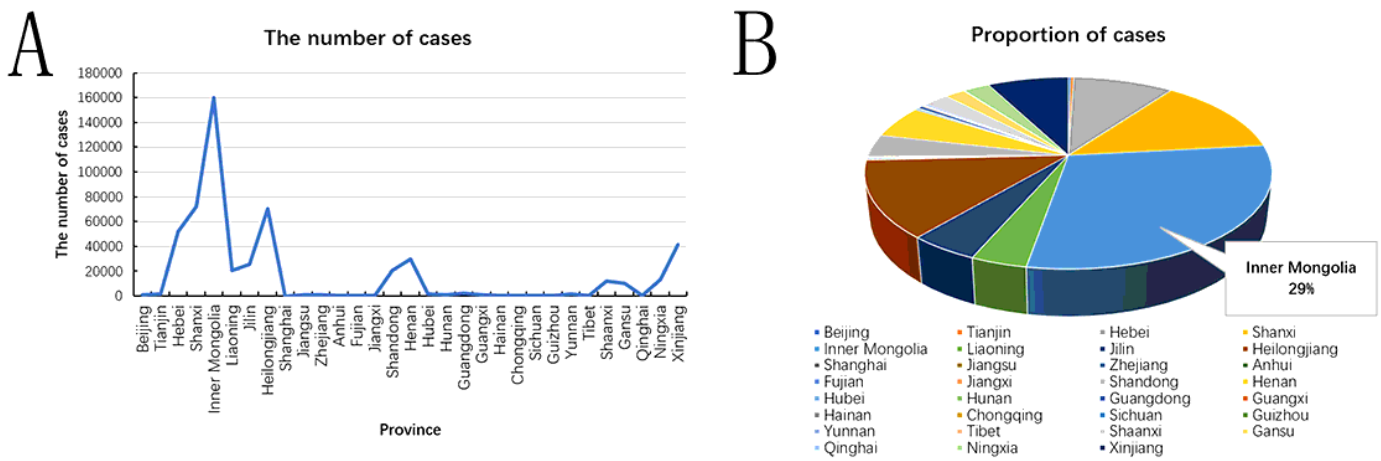

Figure 1

Analysis of human brucellosis in China. (A) The number of cases in different provinces; (B) Proportion of cases in different provinces.

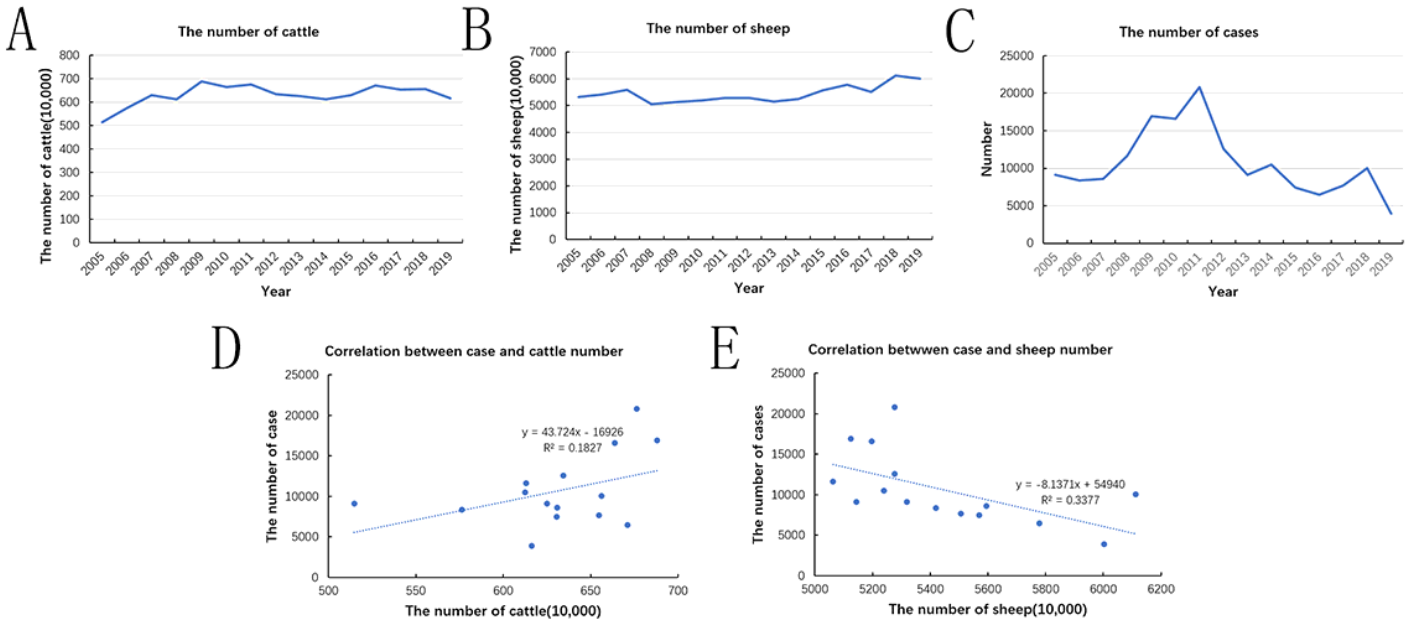

Figure 2

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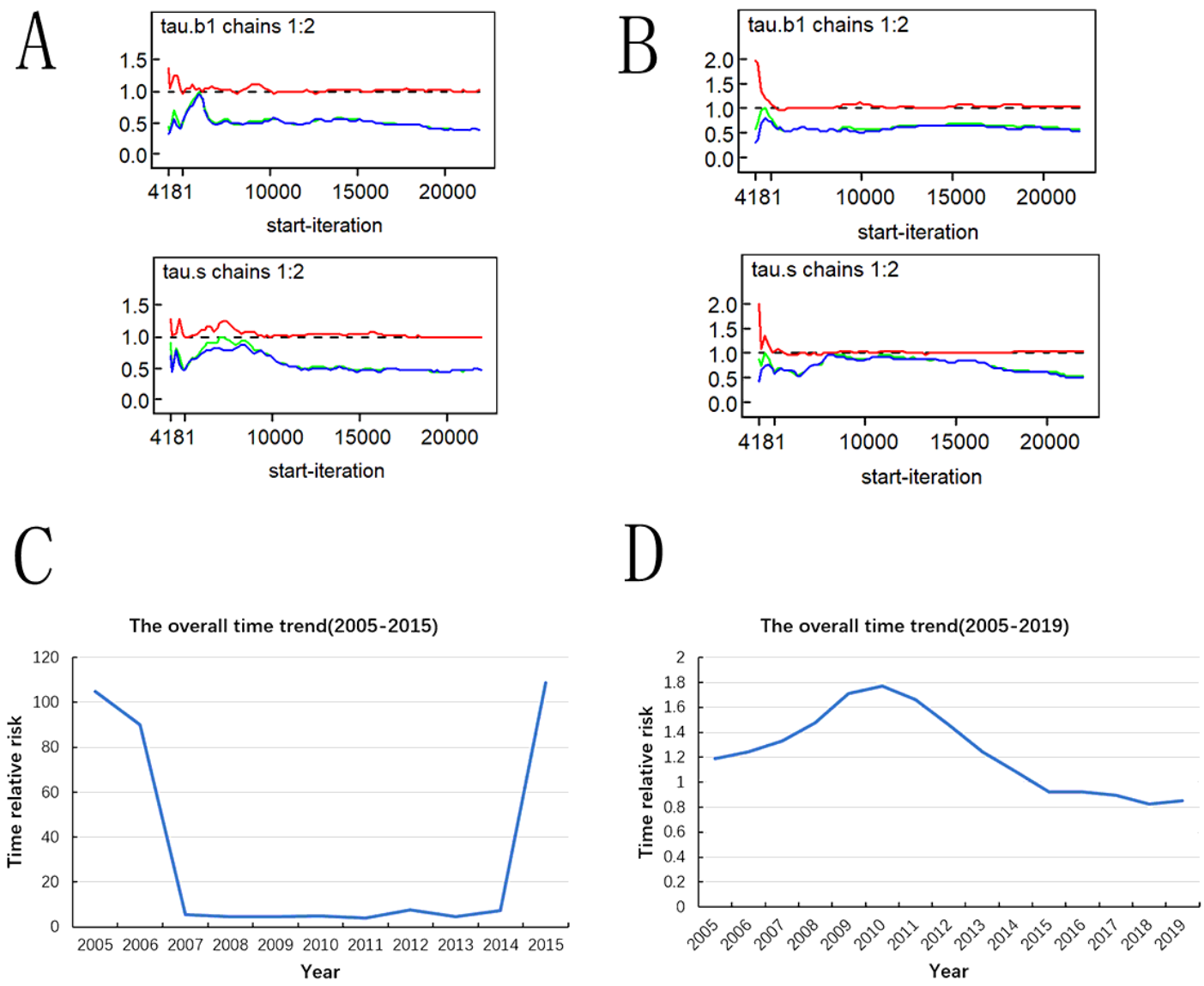

Figure 3

See the Supplemental Files section for the complete figure caption.

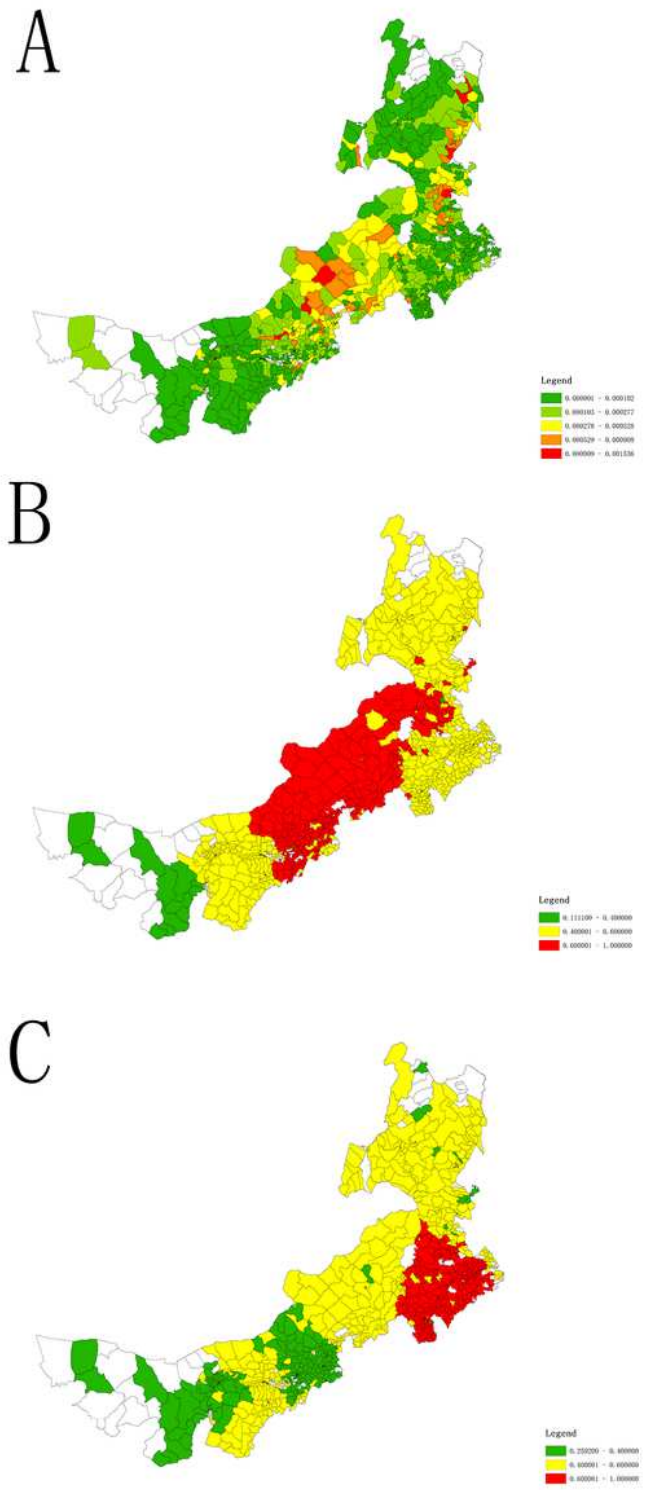

Figure 4

Spatial analysis of human brucellosis from 2005 to 2015 at county level. (A) Distribution of human brucellosis incidence. (B) The cold spots and hot spots of human brucellosis in Inner Mongolia. (C) The trend of risk changes in Inner Mongolia. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research

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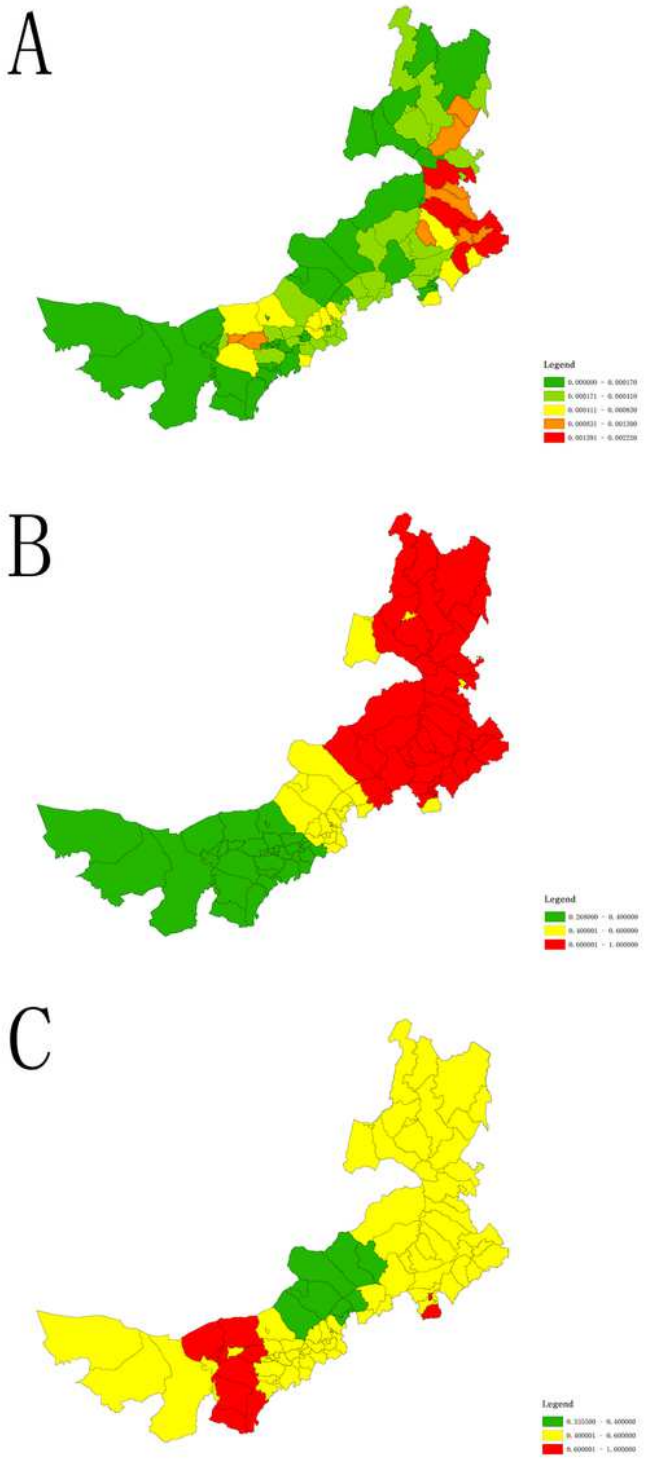

Figure 5

Spatial analysis of human brucellosis from 2005 to 2019 at city level. (A) Distribution of human brucellosis incidence. (B) The cold spots and hot spots of risk in Inner Mongolia. (C) The trend of risk changes in Inner Mongolia. Note: The designations employed and the presentation of the material on this

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