# Supplementary Material

## Supplementary Table S1. Location information of the Lyme disease spirochete detection

| number | longitude | latitude | lc_level | lc_l1 | town_ID | Name | lc_l3 | lc_l4 | host | Year | Source |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 105.68 | 38.84 | 4 | Inner Mongolia | 10 | Alxa | Zuoqi | Bayanhaote | human, tick | — | CNKI |
| 2 | 108.40 | 38.62 | 4 | Inner Mongolia | 8 | Ordos | Etuokeqi | Sumitu | sheep | 2019 | Sampling |
| 3 | 108.42 | 38.72 | 4 | Inner Mongolia | 8 | Ordos | Etuokeqi | Sumitu | sheep | 2015 | Sampling |
| 4 | 109.00 | 38.79 | 5 | Inner Mongolia | 8 | Ordos | Wushenqi | Wulantaole | sheep | 2019 | Sampling |
| 5 | 109.40 | 39.06 | 5 | Inner Mongolia | 8 | Ordos | Wushenqi | Tuke | sheep | 2019 | Sampling |
| 6 | 109.57 | 40.80 | 5 | Inner Mongolia | 9 | Bayan Nur | Wulate Qianqi | Shadegai | goat | 2015 | Sampling |
| 7 | 112.54 | 42.66 | 4 | Inner Mongolia | 6 | Xilin Gol | Suniteyouqi | Duhumu | sheep | 2018 | Sampling |
| 8 | 112.88 | 44.65 | 4 | Inner Mongolia | 6 | Xilin Gol | Sunitezuoqi | Dalaisumu | sheep | 2018 | Sampling |
| 9 | 113.51 | 43.27 | 4 | Inner Mongolia | 6 | Xilin Gol | Suniteyouqi | Aqituwula | sheep | 2018 | Sampling |
| 10 | 114.16 | 43.74 | 4 | Inner Mongolia | 6 | Xilin Gol | Sunitezuoqi | Bayannaoer | sheep | 2017 | Sampling |
| 11 | 114.18 | 42.45 | 5 | Inner Mongolia | 6 | Xilin Gol | Huangqi | Wuritusumu | — | — | CNKI |
| 12 | 114.25 | 42.27 | 5 | Inner Mongolia | 6 | Xilin Gol | Huangqi | Bayintala | sheep | 2017 | Sampling |
| 13 | 115.16 | 42.63 | 4 | Inner Mongolia | 6 | Xilin Gol | Baiqi | Yihezhuoer | sheep | 2018 | Sampling |
| 14 | 115.43 | 42.43 | 4 | Inner Mongolia | 6 | Xilin Gol | Baiqi | Baolagentaohai | sheep | 2018 | Sampling |
| 15 | 115.80 | 45.30 | 4 | Inner Mongolia | 6 | Xilin Gol | Dongwu | Baogedashan | human | 2014 | CNKI |
| 16 | 115.99 | 42.25 | 4 | Inner Mongolia | 6 | Xilin Gol | Zhenlanqi | Shangdu | sheep | 2018 | Sampling |
| 17 | 115.96 | 42.69 | 4 | Inner Mongolia | 6 | Xilin Gol | Zhenlanqi | Sanggendalai | sheep | 2018 | Sampling |
| 18 | 116.19 | 42.79 | 4 | Inner Mongolia | 6 | Xilin Gol | Lanqi | Herisitai | cattle | 2017 | Sampling |
| 19 | 118.28 | 48.23 | 4 | Inner Mongolia | 3 | Hulunbuir | Xinbaerhuzuoqi | Amugulang | sheep | 2018 | Sampling |
| 20 | 118.67 | 43.54 | 3 | Inner Mongolia | 2 | Chifeng | Balinyouqi | — | — | — | CNKI |
| 21 | 118.93 | 45.06 | 5 | Inner Mongolia | 6 | Xilin Gol | Xiwu | Bayanhuazhen | — | — | CNKI |

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|---|---|---|---|---|---|---|---|---|---|---|---|
| 22 | 119.43 | 49.33 | 4 | Inner Mongolia | 3 | Hulunbuir | Chenbaerhuqi | — | — | — | CNKI |
| 23 | 119.53 | 46.60 | 4 | Inner Mongolia | 6 | Xilin Gol | Dongwu | Baogedashan | human | — | CNKI |
| 24 | 119.53 | 47.41 | 4 | Inner Mongolia | 4 | Hinggan | Aershan | — | forest | 2018 | Sampling |
| 25 | 119.74 | 49.22 | 4 | Inner Mongolia | 3 | Hulunbuir | Hailaer | — | — | — | CNKI |
| 26 | 119.76 | 49.15 | 4 | Inner Mongolia | 3 | Hulunbuir | Ewenke | — | Cattle/horse /sheep | — | CNKI |
| 27 | 119.88 | 46.63 | 4 | Inner Mongolia | 6 | Xilin Gol | Dongwu | Baogedashan | sheep sera | — | CNKI |
| 28 | 119.91 | 47.41 | 4 | Inner Mongolia | 4 | Hinggan | Aershan | — | forest | 2020\2021 | CNKI |
| 29 | 120.00 | 51.29 | 4 | Inner Mongolia | 3 | Hulunbuir | Eerguna | ZiranBaohuqu | forest | 2012 | CNKI |
| 30 | 120.09 | 43.87 | 3 | Inner Mongolia | 2 | Chifeng | Alukeerqin | — | sheep | 2019 | Sampling |
| 31 | 120.58 | 52.06 | 4 | Inner Mongolia | 3 | Hulunbuir | Eerguna | ZiranBaohuqu | forest | 2012 | CNKI |
| 32 | 120.78 | 51.27 | 4 | Inner Mongolia | 3 | Hulunbuir | Eerguna | Moerdaoga | — | — | CNKI |
| 33 | 120.81 | 49.31 | 4 | Inner Mongolia | 3 | Hulunbuir | Yakeshi | Mianduhe | forest | 2019 | Sampling |
| 34 | 120.88 | 49.17 | 4 | Inner Mongolia | 3 | Hulunbuir | Yakeshi | Mianduhe | forest | 2018 | Sampling |
| 35 | 120.96 | 50.46 | 4 | Inner Mongolia | 3 | Hulunbuir | Yakeshi | Mianduhe | forest | 2019 | Sampling |
| 36 | 121.01 | 48.99 | 4 | Inner Mongolia | 3 | Hulunbuir | Yakeshi | Mianduhe | forest | 2018 | Sampling |
| 37 | 121.06 | 49.10 | 4 | Inner Mongolia | 3 | Hulunbuir | Yakeshi | Mianduhe | human | — | CNKI |
| 38 | 121.19 | 48.47 | 4 | Inner Mongolia | 3 | Hulunbuir | Yakeshi | Wuerqihan | forest | 2016 | Sampling |
| 39 | 121.21 | 47.99 | 4 | Inner Mongolia | 3 | Hulunbuir | Yakeshi | Taqi | — | — | CNKI |
| 40 | 121.24 | 48.92 | 4 | Inner Mongolia | 3 | Hulunbuir | Genhe | — | forest | 2017 | Sampling |
| 41 | 121.21 | 50.43 | 4 | Inner Mongolia | 3 | Hulunbuir | Genhe | — | forest | 2018 | Sampling |
| 42 | 121.26 | 48.87 | 4 | Inner Mongolia | 3 | Hulunbuir | Yakeshi | Wunuer | forest | 2017 | Sampling |
| 43 | 121.32 | 48.31 | 4 | Inner Mongolia | 3 | Hulunbuir | Yakeshi | Zhuoheyuan | forest | 2018 | Sampling |
| 44 | 121.32 | 49.29 | 4 | Inner Mongolia | 3 | Hulunbuir | Yakeshi | Wuerqihan | forest | 2016 | Sampling |
| 45 | 121.36 | 48.31 | 4 | Inner Mongolia | 3 | Hulunbuir | Yakeshi | Zhuoyuan | forest | 2017 | Sampling |
| 46 | 121.37 | 48.34 | 4 | Inner Mongolia | 3 | Hulunbuir | Yakeshi | Chuoyuan | — | — | CNKI |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 47 | 121.34 | 49.29 | 4 | Inner Mongolia | 3 | Hulunbuir | Yakeshi | Wuerqihan | forest | 2016 | Sampling |
| 48 | 121.40 | 49.57 | 4 | Inner Mongolia | 3 | Hulunbuir | Yakeshi | Wuerqihan | forest | 2017 | Sampling |
| 49 | 121.52 | 49.33 | 4 | Inner Mongolia | 3 | Hulunbuir | Yakeshi | Wuerqihan | forest | 2016 | Sampling |
| 50 | 121.52 | 51.34 | 4 | Inner Mongolia | 3 | Hulunbuir | Genhe | Jinhe | — | — | CNKI |
| 51 | 121.56 | 50.64 | 4 | Inner Mongolia | 3 | Hulunbuir | Genhe | Yitulihe | forest | 2019 | Sampling |
| 52 | 121.55 | 50.79 | 4 | Inner Mongolia | 3 | Hulunbuir | Genhe | — | — | — | CNKI |
| 53 | 121.60 | 50.66 | 4 | Inner Mongolia | 3 | Hulunbuir | Yakeshi | Yitulihe | — | — | CNKI |
| 54 | 121.63 | 121.63 | 4 | Inner Mongolia | 3 | Hulunbuir | Yakeshi | Tulihe | mouse | 2008 | CNKI |
| 55 | 121.69 | 50.49 | 4 | Inner Mongolia | 3 | Hulunbuir | Yakeshi | Tulihe | — | — | CNKI |
| 56 | 121.92 | 48.76 | 4 | Inner Mongolia | 3 | Hulunbuir | Arongqi | Boketu | forest | 2019 | Sampling |
| 57 | 121.96 | 48.74 | 4 | Inner Mongolia | 3 | Hulunbuir | Yakeshi | Mianduhe | forest | 2019 | Sampling |
| 58 | 122.06 | 52.05 | 4 | Inner Mongolia | 3 | Hulunbuir | Genhe | Mangui | — | — | CNKI |
| 59 | 122.50 | 50.66 | 4 | Inner Mongolia | 3 | Hulunbuir | Yakeshi | Keyihe | — | — | CNKI |
| 60 | 123.03 | 50.65 | 4 | Inner Mongolia | 3 | Hulunbuir | Elunchun | Keyihe | tick | 2004.6 | CNKI |
| 61 | 123.54 | 49.43 | 4 | Inner Mongolia | 3 | Hulunbuir | Elunchun | Bilahe | mouse | 2007 | CNKI |
| 62 | 123.73 | 50.61 | 4 | Inner Mongolia | 3 | Hulunbuir | Elunchun | Alihe | — | — | CNKI |
| 63 | 124.61 | 49.74 | 4 | Inner Mongolia | 3 | Hulunbuir | Elunchun | dayangshu | mouse | 2006 | CNKI |
| 64 | 124.63 | 49.74 | 4 | Inner Mongolia | 3 | Hulunbuir | Elunchun | Dayangshu | — | — | CNKI |

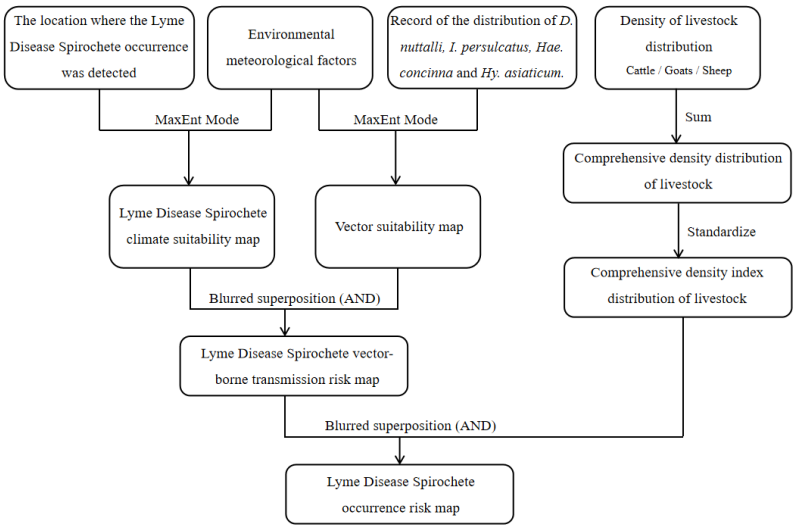
## Supplementary Table S2. Description of 29 potential influencing factors included in model development

| Variable | Description | Source | Data period | Resolution |
|---|---|---|---|---|
| Bio1 | Annual average temperature(℃) | https://www.worldclim.org | 1970-2000 | 2.5 min of arc |
| Bio2 | Mean diurnal range (Mean of monthly max - min temperature) (℃) | https://www.worldclim.org | 1970-2000 | 2.5 min of arc |
| Bio3 | Isothermality (BIO02 ÷ BIO07 ×100) (%) | https://www.worldclim.org | 1970-2000 | 2.5 min of arc |
| Bio4 | Temperature seasonality (standard deviation of mean temperature over 12 months of a year) | https://www.worldclim.org | 1970-2000 | 2.5 min of arc |
| Bio5 | Max temperature of warmest month (℃) | https://www.worldclim.org | 1970-2000 | 2.5 min of arc |
| Bio6 | Min temperature of coldest month (℃) | https://www.worldclim.org | 1970-2000 | 2.5 min of arc |
| Bio7 | Annual range of temperature (BIO05-BIO06) (℃) | https://www.worldclim.org | 1970-2000 | 2.5 min of arc |
| Bio8 | Mean temperature of wettest quarter (℃) | https://www.worldclim.org | 1970-2000 | 2.5 min of arc |
| Bio9 | Mean temperature of driest quarter (℃) | https://www.worldclim.org | 1970-2000 | 2.5 min of arc |
| Bio10 | Mean temperature of warmest quarter (℃) | https://www.worldclim.org | 1970-2000 | 2.5 min of arc |
| Bio11 | Mean temperature of coldest quarter (℃) | https://www.worldclim.org | 1970-2000 | 2.5 min of arc |
| Bio12 | Annual precipitation (mm) | https://www.worldclim.org | 1970-2000 | 2.5 min of arc |
| Bio13 | Precipitation of wettest month (mm) | https://www.worldclim.org | 1970-2000 | 2.5 min of arc |
| Bio14 | Precipitation of driest month (mm) | https://www.worldclim.org | 1970-2000 | 2.5 min of arc |
| Bio15 | Precipitation seasonality (coefficient of variation in rainfall over 12 months of the year) | https://www.worldclim.org | 1970-2000 | 2.5 min of arc |
| Bio16 | Precipitation of wettest quarter (mm) | https://www.worldclim.org | 1970-2000 | 2.5 min of arc |
| Bio17 | Precipitation of driest quarter (mm) | https://www.worldclim.org | 1970-2000 | 2.5 min of arc |
| Bio18 | Precipitation of warmest quarter (mm) | https://www.worldclim.org | 1970-2000 | 2.5 min of arc |
| Bio19 | Precipitation of coldest quarter (mm) | https://www.worldclim.org | 1970-2000 | 2.5 min of arc |
| ELEV | Average altitude (m) | https://www.worldclim.org | 1970-2000 | 2.5 min of arc |
| POP | Population density | http://www.resdc.cn/ | 2020 | 1 km |
| GDP | Gross domestic product | http://www.resdc.cn/ | 2020 | 1 km |
| NDVI | Normalized Difference vegetation Index | http://www.resdc.cn/ | 2023 | 1 km |
| LUT | Land use type | http://www.resdc.cn/ | 2020 | 1 km |
| PH | Soil PH | http://www.geodata.cn/ | 2022 | 250 m |
| SOC | Soil organic carbon content | http://www.geodata.cn/ | 2022 | 250 m |
| Slope | Inclination degree of a specific surface point | Calculated from the Elevation | 1970-2000 | 2.5 min of arc |
| Aspect | Geographical orientation of slope aspect | Calculated from the Elevation | 1970-2000 | 2.5 min of arc |
| LSD | Livestock density (1 head per km²) | https://www.fao.org/faolex/zh/ (Including the density of cattle, sheep, and goat) | 2010 | 5 min of arc |

## Supplementary Methods

*Risk analysis of Lyme Disease Spirochete occurrence*

Occurrence records of Lyme disease spirochetes were imported into ArcMap 10.2 and converted to WGS 1984 shapefiles. MaxEnt was used to predict pathogen climatic suitability across Inner Mongolia. Combined with tick-vector and reservoir-host datasets, multi-layer spatial assessment generated spirochete prevalence-risk maps (workflow, Fig. S1).



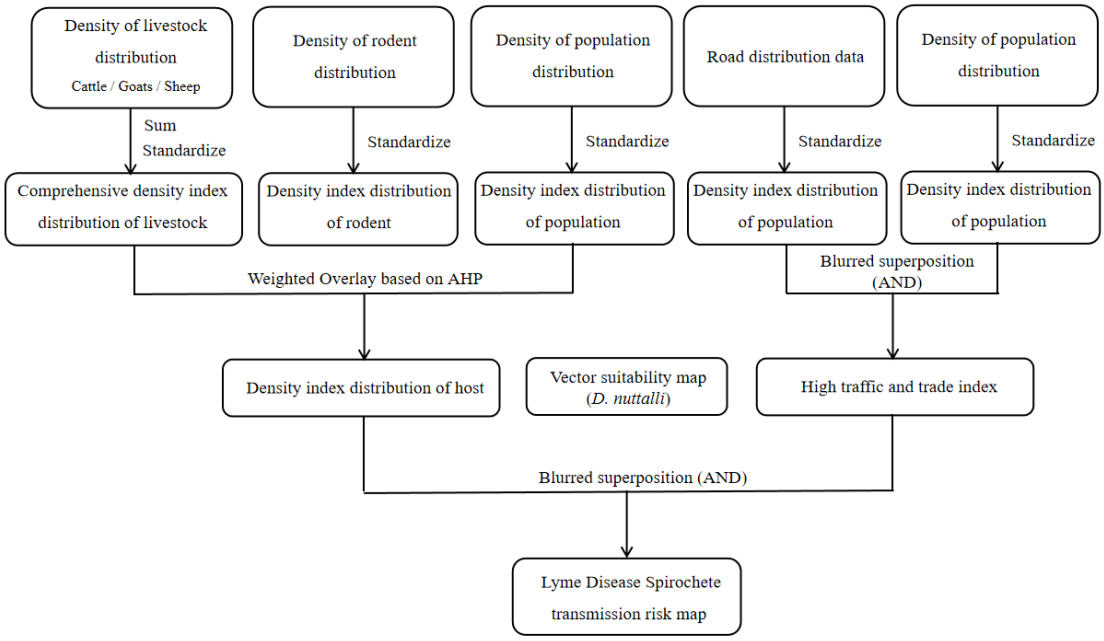

**Supplementary Figure S1.** Flowchart for risk analysis of Lyme disease spirochete occurrence

Cattle, goat and sheep-density layers were processed in ArcGIS and merged via Raster Calculator. Pixel values were normalized to the range 0-1 following Tran et al. [51], matching the scale of climate-suitability and tick-suitability layers for subsequent overlay.We performed two-step fuzzy overlay (ArcMap 10.2). Climate-suitability and tick-vector-suitability layers were overlaid using the "AND" operator to obtain intermediate vector-borne-transmission risk. This layer was further combined with normalized livestock-density data to produce the final risk map. High-risk regions represent overlapping areas with suitable climate, high tick suitability and abundant susceptible livestock, indicating elevated spirochete transmission risk..

*Risk analysis of Lyme Disease Spirochete transmission*

Transportation and livestock trade drive long-distance dispersal of tick-borne pathogens. Highway shapefiles were obtained from the National Fundamental Geographic Information System. Livestock-trading-market locations were acquired from Amap POI API. Kernel-density surfaces for both anthropogenic factors were calculated and normalized, then integrated into a composite traffic-trade index.

Rodent occurrence points were downloaded from GBIF and transformed into density rasters by kernel-density analysis. Rodent, livestock and human-population-density layers were normalized. We applied the Analytic Hierarchy Process (AHP) to assign weights and implemented weighted overlay to generate a unified composite host-density-index dataset (workflow, Fig. S2).




**Supplementary Figure S2.** Flowchart for risk analysis of Lyme Disease Spirochete transmission

*Analytic hierarchy process (AHP) assessment system*

Developed by American operations researcher Saaty, the Analytic Hierarchy Process (AHP) is a multi-criteria decision-making technique. It breaks down complex research problems into interconnected hierarchical levels. Based on expert knowledge and objective field datasets, pairwise comparisons are performed to judge the relative importance of elements within each hierarchy, enabling combined qualitative-quantitative analysis [37]. The hierarchical evaluation framework built in this study is presented below.

**Supplementary Table S3.** AHP assessment system of *Rickettsiae* transmission risk

| Target layer A | Criterion layer B | Indicator layer C |
|---|---|---|
| Lyme Disease Spirochete transmission risk assessment | Host factors $B_1$ | Rodent density $C_1$ |
| | | Livestock density $C_2$ |
| | | Population density $C_3$ |
| | Transportation and trade factors $B_2$ | Road density $C_4$ |
| | | Livestock trading markets density $C_5$ |
| | Vector factors $B_3$ | Vector distribution $C_6$ |

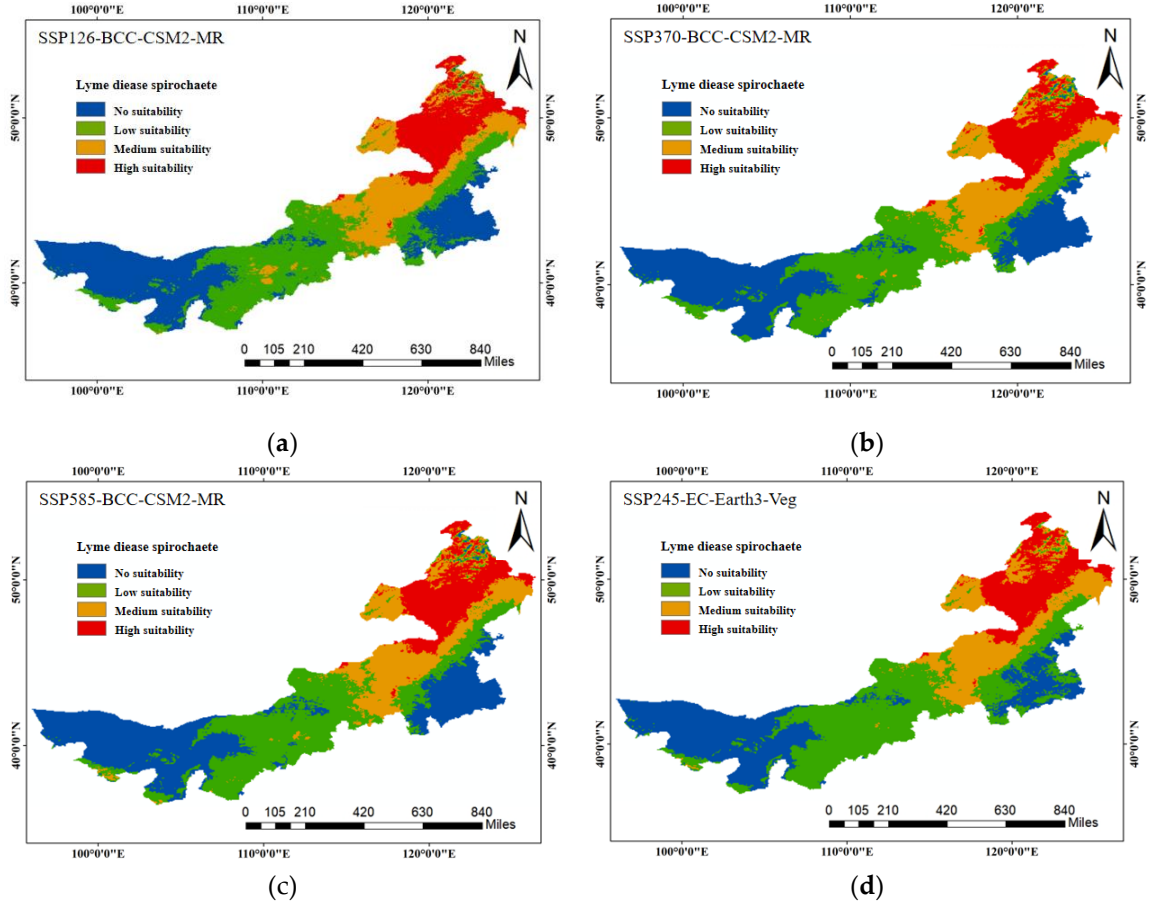
**Supplementary Table S4.** AHP pairwise comparison matrix (A-B)

| A-B | Host factors $B_1$ | Transportation and trade factors $B_2$ | Vector factors $B_3$ | Weight |
|---|---|---|---|---|
| Host factors $B_1$ | 1 | 3/2 | 3/5 | 0.3 |
| Transportation and trade factors $B_2$ | 2/3 | 1 | 2/5 | 0.2 |
| Vector factors $B_3$ | 5/3 | 5/2 | 1 | 0.5 |

**Supplementary Table S5.** AHP pairwise comparison matrix ($B_1$-C)

| $B_1$-C | Rodent density $C_1$ | Livestock density $C_2$ | Population density $C_3$ | Weight |
|---|---|---|---|---|
| Rodent density $C_1$ | 1 | 1 | 9/2 | 0.45 |
| Livestock density $C_2$ | 1 | 1 | 9/2 | 0.45 |
| Population density $C_3$ | 2/9 | 2/9 | 1 | 0.1 |

Consistency test was conducted: For matrix A-B, $\lambda_{max}$= 3.0000,$CI$ = 0, $CR$ = 0 < 0.1, indicating that the matrix passed the consistency test.For matrix $B_1$-C, $\lambda_{max}$= 3.0000, $CI$ = 0, $CR$ = 0 < 0.1, demonstrating indicating good consistency.




**Supplementary Figure S3.** 2050S Distribution Pattern of Lyme disease spirochete. (a) SSP126 of BCC-CSM2-MRs. (b) SSP370 of BCC-CSM2-MR. (c) SSP585 of BCC-CSM2-MR. (d) SSP245 of EC-Earth3-Veg.