Preplanned Studies

Spatiotemporal Epidemiology of Echinococcosis in an Oasis Ecosystem — Xinyuan County, Xinjiang Uygur Autonomous Region, China, 2004–2025

Dilixiati Sali[1]; Hexia Yang[2]; Deyong Ding[2]; Shiyun Wang[1]; Guangzhong Shi[3]; Xinying Xie[4]; Baixue Liu[4]; Zhisheng Chen[1,#]; Jiangshan Zhao[3,#]; Xu Wang[4,#]

Summary

What is already known about this topic?

Echinococcosis is hyperendemic in China, but its spatiotemporal epidemiology within oasis ecosystems remains poorly understood.

What is added by this report?

This study identified temporal uncertainty and spatial heterogeneity, and evidence of dual domestic and sylvatic transmission networks. The annual reported incidence (ARI) of cystic echinococcosis (CE) showed nominal associations with climatic and vegetation factors at lags of 7–8 years, consistent with livestock cycles, whereas the ARI of alveolar echinococcosis (AE) showed nominal associations at lags of 1–3 years, consistent with rodent population dynamics.

What are the implications for public health practice?

These findings support a tailored One Health strategy that distinguishes CE from AE. Aligning interventions with disease-specific ecological lag periods may improve precision and effectiveness of control in oasis regions.

ABSTRACT

Introduction: Xinyuan County, a representative oasis ecosystem, has a high burden of cystic echinococcosis (CE) and alveolar echinococcosis (AE). Characterizing spatiotemporal patterns is essential for understanding oasis transmission and guiding interventions.

Methods: We used 2004–2025 surveillance data to calculate annual reported incidence at township and village levels. Joinpoint regression, spatial autocorrelation and spatiotemporal scan analyses characterized temporal and spatial patterns. Pearson correlation analyses and random forest models identified key factors and optimal lag periods for echinococcosis.

Results: 563 cases were reported (average annual reported incidence: 9.29 per 100,000 population), exhibiting substantial annual fluctuations. CE was hyperendemic and AE sporadic, with both exhibiting spatiotemporal clusters in eastern townships; notably, AE showed stronger high-high spatial autocorrelation in eastern villages (Z=3.03, P<0.01). Climate, hydrology, vegetation, and livestock factors were nominally associated with CE at lags of 7–8 years, and vegetation and grazing factors with AE at lags of 1–3 years. Medical bed availability at a 1-year lag was nominally associated with more reported cases.

Conclusion: Oasis ecology features high temporal uncertainty and spatial heterogeneity in echinococcosis endemicity along the river-corridor, with long-lag livestock-associated patterns for CE and short-lag wildlife-associated patterns for AE. Effective control requires a tailored One Health strategy aligning interventions with disease-specific lag associations.

Echinococcosis is a zoonotic parasitic disease caused by larval *Echinococcus* tapeworms. Its two principal forms are cystic echinococcosis (CE), caused by *Echinococcus granulosus sensu lato*, and alveolar echinococcosis (AE), by *Echinococcus multilocularis* (*1*). Globally, echinococcosis causes approximately 871,000 disability-adjusted life years and costs more than US$3 billion annually. China bears one of the world's heaviest burdens (*2*), with epidemiological patterns varying substantially among regions (*3*). Xinyuan County, in the Ili Kazakh Autonomous Prefecture of Xinjiang, is a distinctive oasis ecosystem where irrigated agriculture coexists with mountainous pastoralism. The county is a high-intensity mixed-endemic focus for CE and AE and among the most severely affected in Xinjiang (*4*). Characterizing its

Copyright © 2026 by Chinese Center for Disease Control and Prevention

long-term, high-resolution spatiotemporal patterns is therefore essential for elucidating oasis transmission and informing targeted interventions.

We analyzed township- and village-level echinococcosis surveillance data from Xinyuan County, 2004–2025. All cases from passive reporting or active detection were verified and registered under the national Diagnostic Criteria for Echinococcosis (WS 257–2006). Population denominators were the mean of the 2010 and 2020 national census populations. We calculated the annual and average annual reported incidence (ARI and AARI) per 100,000 population, with the standard deviation (SD), coefficient of variation (CV), and 95% confidence interval (*CI*). We assessed temporal trends using Joinpoint 6.1.0 (National Cancer Institute, Rockville, MD, USA), applying a grid-search method to identify inflection points and estimate annual and average annual percentage change (AAPC). Spatial analyses were performed in ArcGIS 10.8 (Esri, Redlands, CA, USA); global and local Moran's I statistics assessed spatial autocorrelation and identified local clusters, respectively. Spatiotemporal scan analyses in SaTScan 10.3.2 (Information Management Services, Calverton, MD, USA) used a discrete Poisson model to identify significant clusters and calculate relative risks (RRs) and log-likelihood ratios (LLRs). The analysis included 48 multisource covariates for 2000–2024 representing climate, hydrology, vegetation, land use, and socioeconomic conditions. We calculated pairwise Pearson correlations within each category. Variable pairs with $|r|>0.7$ were submitted to a two-round Delphi consultation involving three experts, who reached consensus on retention based on biological plausibility, data quality, and relevance to transmission. For each retained variable, we correlated ARI with lags of 0–8 years and defined the optimal exposure window as the lag with the strongest correlation. Random forest regression quantified variable importance. We selected the 10 highest-ranked predictors and visualized their response curves with partial dependence plots. All remaining statistical analyses were performed in R 4.5.1 (R Foundation for Statistical Computing, Vienna, Austria).

From 2004 to 2025, 563 echinococcosis cases were reported in Xinyuan County (AARI, 9.29 per 100,000 population; 95% *CI*: 8.55–10.09). Overall, 508 CE cases were reported (AARI, 8.38 per 100,000 population; 95% *CI*: 7.68–9.14) (Figure 1A). The ARI of CE increased despite year-to-year fluctuations (AAPC=12.35%, $P<0.05$) (Figure 1B). In comparison, 55 AE cases were reported (AARI, 0.91 per 100,000 population, 95% *CI*: 0.67–1.15) (Figure 1C). The ARI of AE also increased, with year-to-year fluctuations and more rapid recent growth (AAPC=5.18%, $P<0.05$) (Figure 1D).

Spatially, 11 of 12 townships had an AARI of CE>5 and four an AARI of AE>1 per 100,000 population. Nalati had the highest AARI for both CE and AE (16.21 and 3.41 per 100,000 population, respectively). The ARI was highly variable in Kansu and Tuergen for both CE (SD>15.00; CV>100.00) and AE (SD>3.00; CV>200.00) (Figure 2). Spatiotemporal scan analysis identified significant eastern clusters for CE in Nalati, Kansu, Areletuobie, and Alemale during 2014–2024 (RR=2.05; LLR=23.72; $P<0.05$) and for AE in Nalati, Kansu, Areletuobie, Alemale, and Biesituobie during 2013–2021 (RR=6.26; LLR=20.26; $P<0.05$). At the village level, the global Moran's I for CE AARI was 0.03 (Z=0.96; $P=0.34$), indicating no significant global autocorrelation and suggesting heterogeneity within townships. By contrast, AE showed significant positive spatial autocorrelation (global Moran's I=0.11; Z=3.03; $P<0.01$). Local Moran's I identified AE hot spots (high-high) in the east and cold spots (low-low) in the west. These clusters followed river-corridor near the county's central east–west axis.

Of the 48 candidate predictors, 22 were retained after correlation analysis (Figures 3A, 3B, and 3D). In the random forest model for CE, climatic, hydrological, and vegetation factors at lags of 7–8 years showed the strongest nominal associations with ARI ($R^2=0.91$), then socioeconomic and anthropogenic factors at lags of 2–4 years and land-cover factors at 0–1 year. A higher ARI of CE was positively correlated with greater specific humidity and runoff at 8-year lags, vegetation coverage at a 7-year lag, sheep density at a 4-year lag, and shrub area and medical bed availability at 1-year lags (Figure 3C). In the model for AE ($R^2=0.91$), vegetation factors at a 3-year lag, climatic factors at lags of 2–3 years, and anthropogenic factors at lags of 1–3 years showed the strongest nominal associations with ARI. The ARI of AE was positively correlated with a higher precipitation rate and grazing intensity at 3-year lags, specific humidity at a 2-year lag, vegetation coverage at an 8-year lag, and medical bed availability at a 1-year lag (Figure 3E). For multiple comparisons across 198 factor-lag tests, we

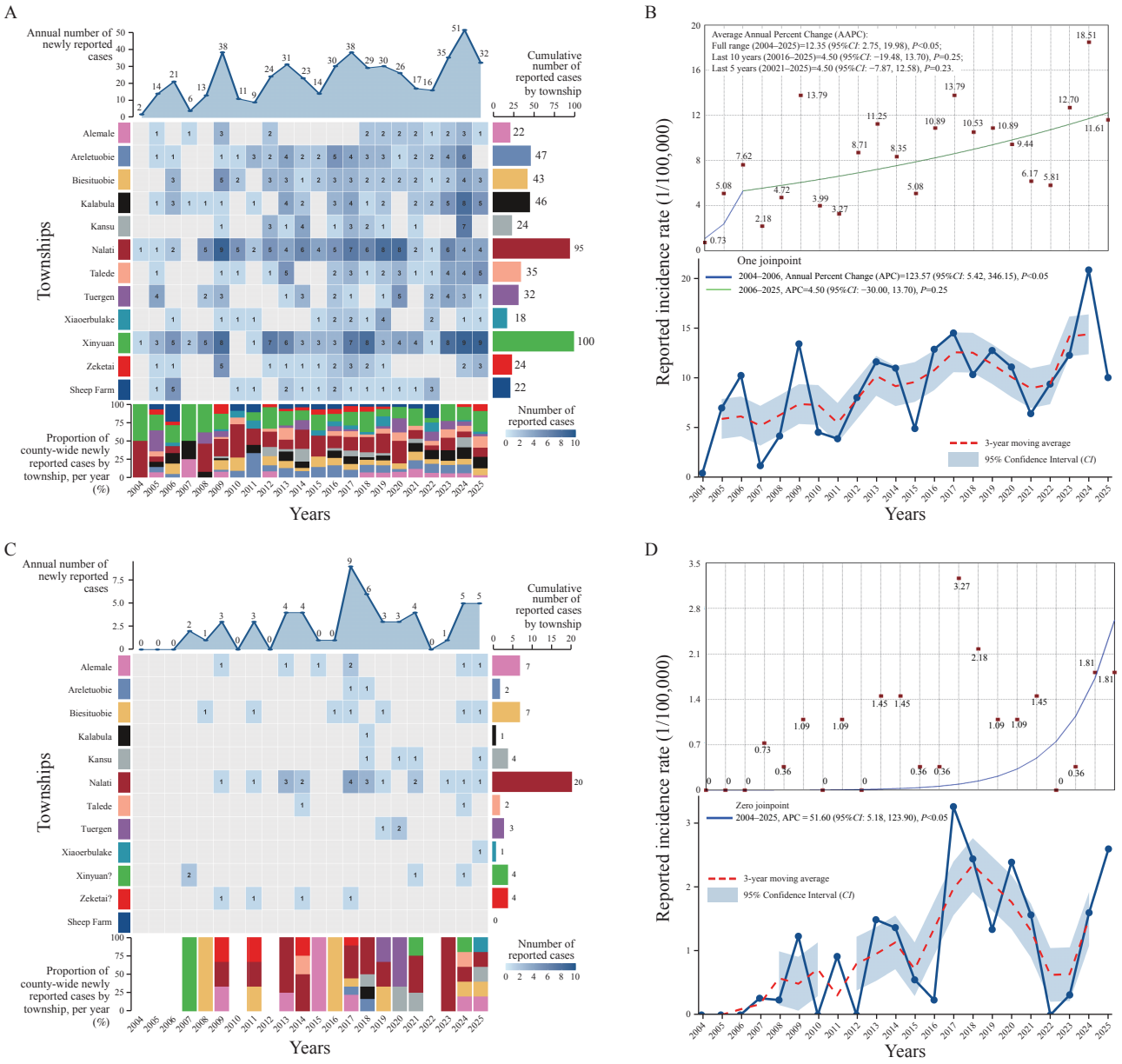


FIGURE 1. Temporal trends in reported cases and annual reported incidence (ARI) for cystic echinococcosis (CE) and alveolar echinococcosis (AE) in Xinyuan County, Xinjiang, 2004–2025. (A) Spatiotemporal distributions of CE cases across 12 townships. (B) ARI and temporal trends for CE. (C) Spatiotemporal distributions of AE cases across 12 townships. (D) ARI and temporal trends for AE.

Note: Annual active screening in Xinyuan County remained stable at approximately 11,000–15,000 individuals during 2007–2025. In (A) and (C), the upper graph shows annual county-level case counts, the right sidebar shows cumulative cases by township, and the lower graph shows the annual percentage distribution of cases by township. In (B) and (D), the upper graphs show Joinpoint regression results, and the lower graphs show 3-year moving averages.

applied a global Benjamini–Hochberg false discovery rate correction. After correction, only specific humidity at an 8-year lag remained significantly associated with CE (q=0.0055); no other initially significant correlation remained significant. Accordingly, the remaining lag patterns should be interpreted as exploratory signals rather than robust relationships.

DISCUSSION

This study characterized mixed-endemic echinococcosis in Xinyuan County, a representative Xinjiang oasis ecoregion. The county had hyperendemic CE foci in most townships, with hyperendemicity defined by the World Health

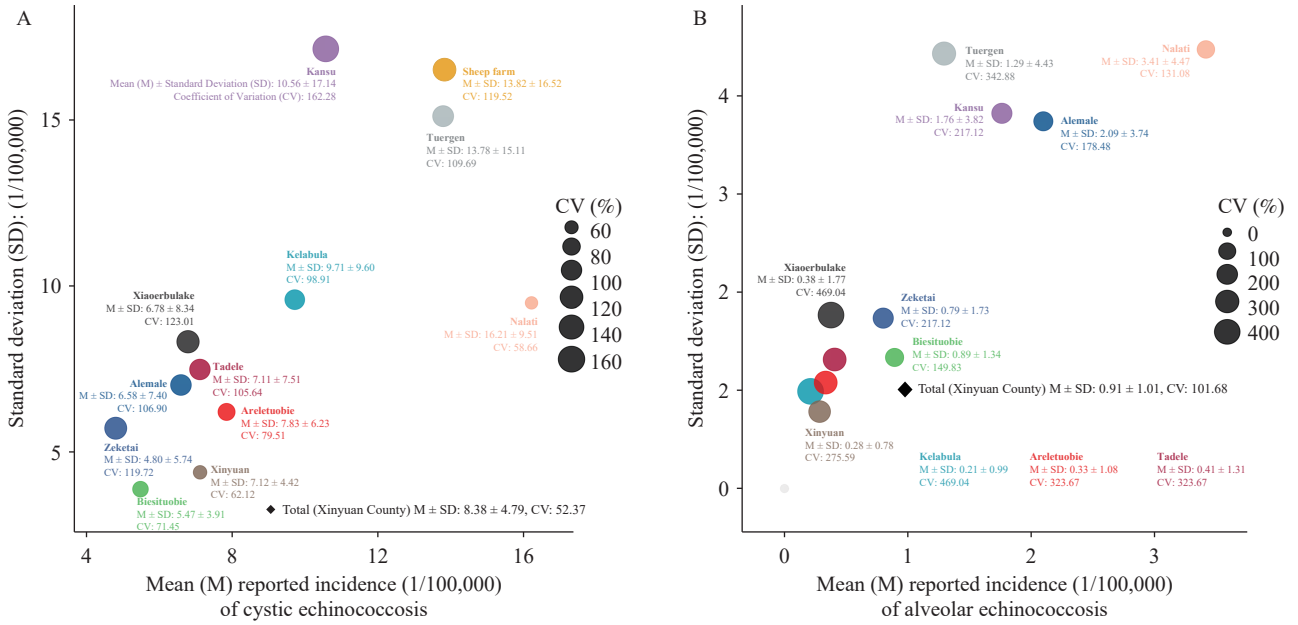


FIGURE 2. Average annual reported incidence (AARI), standard deviation (SD), and coefficient of variation (CV) of echinococcosis at the county and township levels, Xinyuan County, Xinjiang, 2004–2025. (A) AARI, SD and CV of cystic echinococcosis (CE). (B) AARI, SD and CV of alveolar echinococcosis (AE).

Organization as >5 per 100,000 population annually (*2*), whereas AE was more concentrated in the east.

The ARI varied substantially among years, potentially reflecting oasis ecosystems' sensitivity to climatic and hydrological perturbations (*5*). Spatially, the isolation of oasis settlements and their linear distribution along river systems may contribute to the marked heterogeneity in disease occurrence (*6*). Cases clustered along the central river-corridor rather than in the extensive contiguous clusters reported on the Tibetan and Loess Plateaus. Endemicity followed a pronounced east–west gradient, with the highest burden in eastern Xinyuan County, particularly Nalati Township. Extensive alpine meadows here support intensive livestock production and wildlife habitats, consistent with overlapping domestic and sylvatic transmission networks. These findings identify eastern Xinyuan County as a priority for targeted surveillance and control.

Nominal factors associated with ARI differed between CE and AE. For CE, climatic, hydrological, and vegetation factors, including specific humidity and runoff, showed nominal associations at lags of 7–8 years. These lags are consistent with livestock (e.g., sheep, cattle) population turnover and the established domestic transmission cycle of *Echinococcus granulosus sensu lato* (*7*). By contrast, environmental factors showed nominal associations with AE at shorter lags of 1–3 years. These patterns are consistent with small-mammal (mainly vole) sensitivity to microclimatic variation and with the sylvatic transmission cycle of *Echinococcus multilocularis* (*8*). Sheep density correlated more strongly with CE than AE, whereas grazing intensity showed the opposite pattern, supporting distinct transmission pathways. Medical bed availability at a 1-year lag was nominally associated with both diseases, possibly because improved healthcare access increased detection rather than transmission. Although exploratory, these disease-specific lag patterns suggest plausible temporal scales for future intervention studies.

Several limitations should be noted. First, the 22-year observation period may be insufficient for a disease with long latency. In addition, denominators derived from decennial censuses may not capture migration, and ARI reflects variation in surveillance and diagnostic practices rather than true incidence. Second, the ecological, aggregate-level design could not account for individual-level confounders, and unmeasured socioecological factors may have introduced residual confounding; thus, the observed associations should not be interpreted as causal. Third, the proposed transmission cycles were inferred from environmental proxies and human case data without direct animal-host measurements. Although the identified lag periods are epidemiologically plausible, further field and experimental studies with independent or prospective validation are needed to

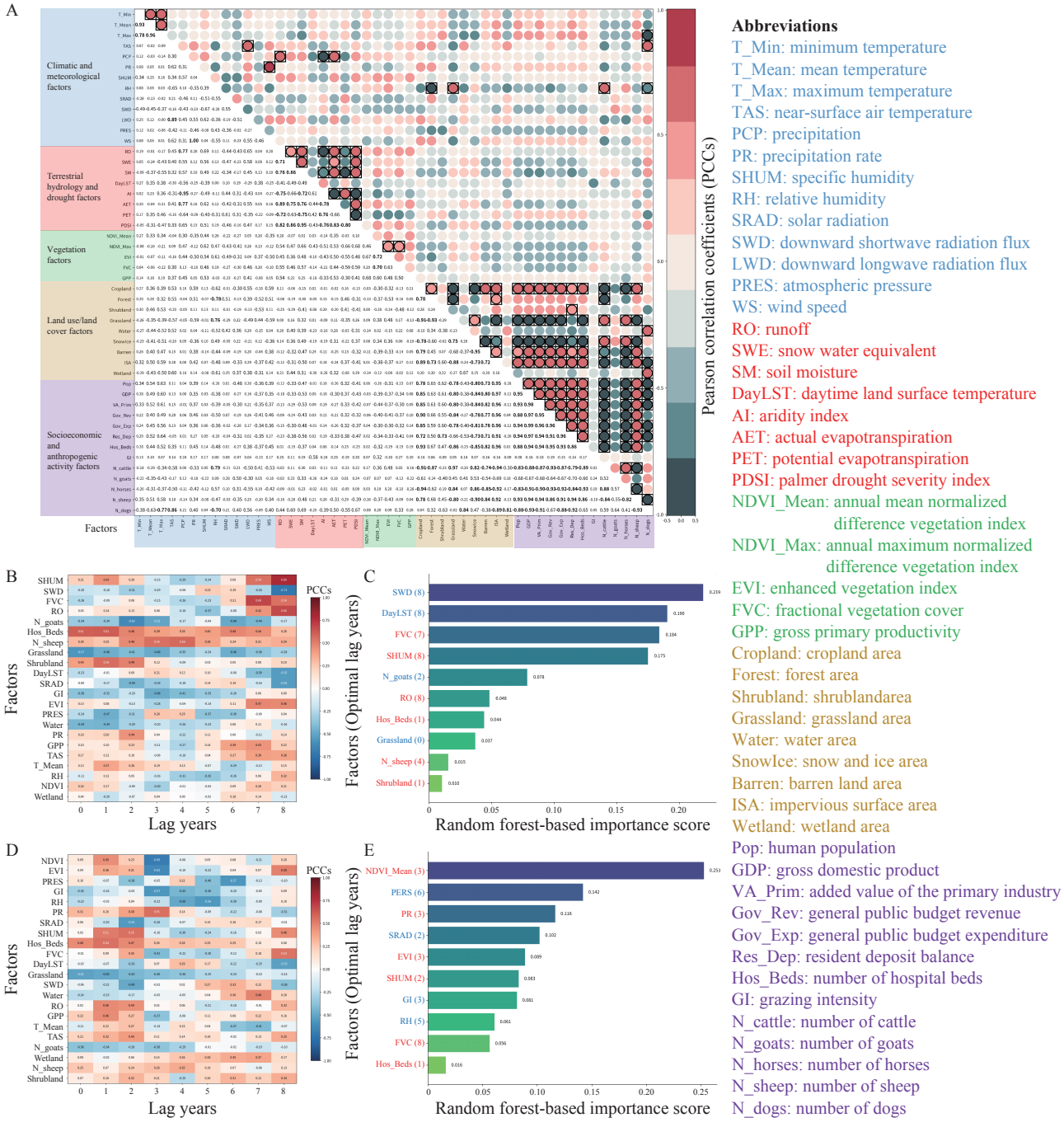


FIGURE 3. Environmental factors associated with the annual reported incidence (ARI) of cystic echinococcosis (CE) and alveolar echinococcosis (AE) in Xinyuan County, Xinjiang, 2004–2025. (A) Pearson correlation matrix for 48 environmental factors in Xinyuan County during 2000–2025. (B) Pearson correlation matrix between 22 selected environmental factors at lags of 0–8 years and the ARI of CE. (C) Random forest importance scores for the 10 highest-ranked predictors at specific lags for CE. (D) Pearson correlation matrix between 22 selected environmental factors at lags of 0–8 years and the ARI of AE. (E) Random forest importance scores for the 10 highest-ranked predictors at specific lags for AE.

define exposure windows and confirm these associations.

These findings support a tailored One Health strategy for oasis regions. Control programs should distinguish CE from AE and account for the distinct ecological settings of transmission. Coordinated interventions should address domestic and sylvatic cycles across human settlements, livestock-production areas, and wildlife habitats. The observed disease-specific lag periods may help time future interventions,

but their effectiveness should be evaluated prospectively before these exploratory associations determine control schedules.

Conflicts of interest: No conflicts of interest.

Funding: This study was supported by the National Natural Science Foundation of China (grant No. 82404325) and the Research Projects of the Shanghai Municipal Health Commission (grant No. 20254Y0176).

doi: 10.46234/ccdcw2026.215

[#] Corresponding authors: Xu Wang, wangxu@nipd.chinacdc.cn; Zhisheng Chen, ylzaids@163.com; Jiangshan Zhao, zjscdc@163.com.

[1] Ili Kazakh Autonomous Prefecture Center for Disease Control and Prevention (Ili Kazakh Autonomous Prefecture Health Supervision Institute), Ili, Xinjiang Uygur Autonomous Region, China; [2] Xinyuan County Center for Disease Control and Prevention (Xinyuan County Health Supervision Institute), Ili, Xinjiang Uygur Autonomous Region, China; [3] Center for Disease Control and Prevention of Xinjiang Uygur Autonomous Region, Key Laboratory of Vector-borne Infectious Diseases in Xinjiang, Urumqi, Xinjiang Uygur Autonomous Region, China; [4] National Institute of Parasitic Diseases, Chinese Center for Disease Control and Prevention; Chinese Center for Tropical Diseases Research; National Key Laboratory of Intelligent Tracking and Forecasting for Infectious Diseases; National Health Commission (NHC) Key Laboratory on Parasite and Vector Biology; World Health Organization Collaborating Centre for Tropical Diseases, Shanghai, China.

Copyright © 2026 by Chinese Center for Disease Control and Prevention & Chinese Academy of Preventive Medicine. All content is distributed under a Creative Commons Attribution Non Commercial License 4.0 (CC BY-NC).

Submitted: August 07, 2026
Accepted: October 10, 2026
Issued: October 23, 2026

REFERENCES

1. Wang X, Zuo QQ, Xue CZ, Liu BX, Kui Y, Deng XY, et al. Niche analysis of spatial distribution and host selection of global *Echinococcus* species - Worldwide, up to June 30, 2024. China CDC Wkly 2025;7(26):889 – 94. https://doi.org/10.46234/ccdcw2025.147.
2. Wang X, Kui Y, Xue CZ, Wang Q, Zheng CJ, Zhao JS, et al. Past, present and future epidemiology of echinococcosis in China based on nationwide surveillance data 2004-2022. J Infect 2025;90(3):106445. https://doi.org/10.1016/j.jinf.2025.106445.
3. Ma T, Wang Q, Hao MM, Xue CZ, Wang X, Han S, et al. Epidemiological characteristics and risk factors for cystic and alveolar echinococcosis in China: an analysis of a national population-based field survey. Parasit Vectors 2023;16(1):181. https://doi.org/10.1186/s13071-023-05788-z.
4. Wang X, Gongsang QZ, Yang SJ, Wang Y, Liao S, Shi GZ, et al. Climate change reshapes the potential transmission risk of human alveolar and cystic echinococcosis in western China: a projection based on MaxEnt models. Infect Dis Poverty 2026;15(1):97. https://doi.org/10.1186/s40249-026-01482-1.
5. Chen P, Wang S, Liu YX, Wang YP, Li ZD, Wang YJ, et al. Spatio-temporal patterns of oasis dynamics in China's drylands between 1987 and 2017. Environ Res Lett 2022;17(6):064044. https://doi.org/10.1088/1748-9326/ac740b.
6. Zhang WB, Ma LB, Li HB, Wang X. Trends in the future evolution of rural settlements in oasis-desert areas under water use simulation scenarios: take the Hexi Corridor region of China as an example. Landsc Urban Plan 2024;248:105110. https://doi.org/10.1016/j.landurbplan.2024.105110.
7. Bai XY, Yin F, Ru A, Tian W, Chen QW, Chai R, et al. Effect of slaughter age and postmortem aging time on tenderness and water-holding capacity of yak (*Bos grunniens*) *longissimus thoracis* muscle. Meat Sci 2023;202:109201. https://doi.org/10.1016/j.meatsci.2023.109201.
8. Wang X, Xue CZ, Deng XY, Chen QL, Li CY, Liu BX, et al. Seasonal population dynamics and dietary switching of *Vulpes* spp. amplify Echinococcus spp. transmission in the eastern Tibetan Plateau: implications for wildlife-mediated zoonotic risks. BMC Vet Res 2025;21(1):475. https://doi.org/10.1186/s12917-025-04907-5.