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Spatial change, time tendency and projection to HIV/AIDS incidence in an eastern province of China

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Objectives As the second most populous province in China, it would have public implications to analyze spatial change, time tendency and prediction analysis of the acquired immunodeficiency syndrome (AIDS) epidemic in Shandong Province. Statistical projection study. Spatial autocorrelation model and spatiotemporal scanning analysis were used to describe the spatial and temporal distribution of HIV/AIDS incidence in Shandong Province from 2012 to 2022, and geographical weighted regression model and geographic detector model were used to analyze the influencing factors. The annual incidence rate of AIDS in Shandong Province from 2023 to 2030 was predicted by using the fitted Autoregressive Integrated Moving Average model (ARIMA). From 2012 to 2022, the incidence of AIDS in Shandong Province grows from 1/10 thousand to 2.48/10 thousand. Spatial regressions showed that the tertiary sector GDP ratio is the factor with the highest intensity of influence. AIDS incidence shows an overall decreasing trend from east to west across Shandong Province. It is predicted that the AIDS incidence rate in Shandong province will continue to rise from 2023 to 2030, with a projected rate of 6.33/10 thousand in 2030. From 2012 to 2022, the incidence of AIDS in Shandong Province increased and then decreased, and regional differences were revealed as well. It is predicted that the incidence of AIDS in Shandong Province would have an increasing trend from 2023 to 2030.

Keywords AIDS prediction, Spatial correlation model, Spatiotemporal scanning analysis, ARIMA model, Shandong province, China

Acquired immune deficiency syndrome (AIDS) is an infectious disease caused by infection with the human immunodeficiency virus (HIV), which is charactered by a defect in the immune function of T-cells and poses a serious threat to human health[1,2]. Since HIV is present in human blood, semen, vaginal secretions and breast milk, it is transmitted in many ways, sexually, through blood and vertically from mother to child[3]. HIV infection can disrupt the human immune system and combine with various infections or malignancies, ultimately leading to death[4]. The widespread epidemic of AIDS worldwide has had a great negative impact on the lives of those affected, on the economic development of countries and on social stability[5,6]. By the time 2019 ended, about 38 million people were infected by HIV[7]. By the end of 2020, there were 1,053,000 people living with HIV in China, with a cumulative total of 351,000 reported deaths[8]. The United Nations AIDS Programme released the report "2022 Global AIDS Progress Report: In Danger ". Under the multiple impacts of the COVID-19 pandemic and other global crises such as climate change, food insecurity and natural disasters, progress in the response to the AIDS pandemic has stalled over the past two years. The resources for the prevention and treatment of people living with HIV are diminishing, putting millions of lives at risk[9].

Shandong Province, located on the eastern coast, is the second most populous province in China[10]. The high mobility of the population promotes the spread of infectious diseases, and there are regional imbalances in economic development[11]. Moreover, due to the unbalanced allocation of health care resources in Shandong Province, some patients in the western region have not been tested in a timely manner, making the spatial distribution of HIV/AIDS in Shandong Province vary significantly[12]. The number of living HIV/AIDS cases in

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Shandong Province is increasing year by year, and the task of prevention and treatment is arduous[13].The major public health problem of HIV infection poses a huge challenge to governments and medical institutions[14,15].

Currently, most of the epidemiological studies on AIDS focuses on analyzing special populations and social characteristics or limited to descriptive or relational analysis of AIDS[16,17], but there were few research on spatial model analysis of AIDS incidence. Moreover, most of the available research only described the temporal tendency of AIDS without prediction of potential changes in future[18–20], which only reflected the history trend without referential value for the government's decision. As a result, existing studies are limited in predicting the future incidence of HIV in Shandong Province. This study aimed to develop a spatial distribution map of AIDS incidence in Shandong Province, analyze the spatial correlation of AIDS incidence in each city, examine the influence of macro factors on the incidence of AIDS and to predict incidence of AIDS in the future. Our study is the first study in Shandong Province to examine both the spatial change, time tendency of HIV and to predict its future incidence trends. This study is conducive to the regionalized prevention and control of AIDS in Shandong Province, strengthens the screening of AIDS in economically disadvantaged areas, and provides evidence for the formulation and improvement of AIDS prevention and control strategies and measures as well as the evaluation of their effects in Shandong Province.

Materials and methods

Data sources

The demographic data were from the annual statistical bulletin of each city in Shandong Province (http://tjj.shandong.gov.cn). Data on AIDS in Shandong Province from 2012 to 2022 were obtained from the AIDS/HIV comprehensive response information management system (CRIMS) of the China Information System for Disease Control and Prevention. The AIDS/HIV comprehensive response information management system is an information management platform that integrates the functions of collecting, analyzing and utilizing data for comprehensive AIDS prevention and control work. The AIDS epidemic is closely related to the living environment of infected people, therefore, in the analysis of factors influencing the spatial and temporal distribution of AIDS, with reference to the previous literature[21], we have analysed factors such as economic and social development, population distribution and mobility and medical resources: (1) economic and social development : per capita GDP, proportion of tertiary industry GDP and urbanization rate, (2) population distribution and mobility: population density and highway mileage, (3) medical resources: number of beds in health institutions per thousand population and medical and health institutions.

Statistical analysis

Global and local spatial autocorrelation analyses using the spatial autocorrelation tool of ArcGIS 10.3 software to build Spatial Autocorrelation model. Construction of Geographical Weighted Regression Model for impact factor analysis using the Geographically Weighted Regression Tool in ArcGIS 10.3 software. And we used Geodetector 2015 software to conduct a Geographic Detector model.

Spatial autocorrelation model

Spatial autocorrelation analysis[9], is a statistical model employed to characterize the correlation between spatial variables. The primary objective is to ascertain the spatial correlation of a specific variable and quantify the degree of correlation. This analytical approach could explore the spatial distribution characteristics of diseases based on the similarity of disease-related attributes and locations. It further investigates the spatial clustering and differentiation of diseases. The model generally contains two parts: global and local spatial autocorrelation, in which the global spatial autocorrelation identifies whether the spatial distribution of the outbreak is spatially correlated in the whole and to what extent, based on the calculated Moran´s *I*. Moran's I is calculated as:

$$Moran'\,s\,I=\frac{n\sum_{i=1}^{n}\sum_{j\neq 1}^{n}W_{ij}\left(x_i-\bar{x}\right)(x_j-\bar{x})}{n\sum_{i=1}^{n}\sum_{j\neq 1}^{n}W_{ij}\sum_{i=1}^{n}\left(x_i-\bar{x}\right)^2}$$

Local autocorrelation analysis can further identify the degree of spatial dependence and the clustering pattern of the epidemic in local space by drawing the clustering map of Local Indicators of Spatial Association (Local Indicators of Spatial Association, LISA) and determining the distribution of the epidemic in the spatial "High-High", "Low-Low", "Low-High", "Low-Low", "Low-High" and "Low-Low". By drawing maps of spatial clustering of "High-High", "Low-Low", "Low-High", and "Low-Low", the spatial dependence of the epidemic on local space and the pattern of clustering can be further identified.

Spatiotemporal scanning analysis

Spatiotemporal scanning analysis is a methodology employed to identify clustering of a specified attribute within a defined research area. The determination of the clustering range is achieved through the calculation of spatiotemporal scanning statistics. Underpinned by the "existence root model theory," space-time scanning facilitates a comprehensive observation and holistic description of phenomena from both temporal and spatial perspectives. This approach guides individuals in making scientifically informed judgments on the studied phenomena.

Geographical weighted regression model

The Geographical Weighted Regression (GWR) model is a spatial analysis technique. Functioning as a semi-parametric model that captures spatial heterogeneity, the GWR model generates distinct estimation coefficients for each research unit. This approach effectively reflects the varying impact of variables across different geographical locations, enabling the characterization of spatial differentiation in the influence of different factors on explanatory variables. According to previous literature[21], the initial selection of macro-influential factors involves seven variables: per capita GDP (X1), proportion of tertiary industry GDP (X2), population density (X3), highway mileage (X4), number of beds in health institutions per thousand population (X5), urbanization rate (X6), and medical and health institutions (X7). The GWR model for this study is expressed as:

$$y_i = \beta_0(\mu_i, v_i) + \sum_{i=1}^{k} \beta_j(\mu_i, v_i)\, x_{ij} + \epsilon_i$$

where x_i and y_i are the regression independent variable and dependent variable respectively; β_0, $\beta_0\ (u_i, v_i)$ are global and ith sample constant terms, respectively; $\beta_j\ (u_i,v_i)$ refers to the regression coefficient of the jth parameter of the ith sample, reflecting the spatial differentiation of the impact of different parameters on the sample, the positive and negative sign of the coefficient indicates the positive and negative correlation between the parameter and the spatial location, and the size indicates the strength of the correlation; (u_i, v_i) refers to the ith spatial coordinate; x_{ij} refers to the jth parameter value of the ith sample; ε_i stands for the random error term; and k represents the number of independent variables.

Geographic detector model

The Geographic Detector serves as a tool for assessing the spatial differentiation of a single variable and can also be employed to examine the coupling of the spatial distribution of two variables. This allows for the identification of potential interactions between the two variables. The formula for the Geographic Detector model is expressed as:

$$q = 1 - \frac{1}{N\sigma^2} \sum_{h}^{L} N_h \sigma_h^2$$

where h = 1, …, L is the stratification of the variable Y or factor X; N_h and N are the number of cells in stratum h and the whole region, respectively; and σ_h^2 and σ^2 are the variance of the Y-values in stratum h and the whole region, respectively.

Autoregressive integrated moving average, model

The Autoregressive Integrated Moving Average (ARIMA) model stands as one of the methods used for time series prediction and analysis. Rooted in the change trend of data series and the correlation between different time points, the model predicts the future development of data over a specified time period while ensuring stationarity.

The 2019 outbreak of COVID-19 resulted in an anomalous HIV positive test rate, which affected the accuracy of the incidence data statistics. To mitigate this impact, we opted to exclude the data from 2020 to 2022 when predicting AIDS incidence.

Results

Time change of AIDS epidemic in Shandong province

From 2012 to 2022, the incidence of HIV/AIDS in Shandong Province showed a general trend of increasing and then decreasing. During this period, the annual incidence of HIV/AIDS was highest in 2021, 3.12 times higher than in 2012, with the average growth rate of HIV/AIDS incidence in Shandong Province for ten years was 9.5%. 2012–2015 is the stage of rapid growth, with an average annual growth rate of 32.19% in four years. 2016–2019 is the stage of slow growth, with an average annual growth rate of 10.18% in four years. 2019–2022 is the stage of fluctuation, as shown in Fig. 1.

Spatial distribution of AIDS epidemic in Shandong province

Six time points, namely 2012, 2014, 2016, 2018, 2020, and 2022, were chosen to examine the spatial distribution of the epidemic based on the corresponding data. Employing the natural break point method, a descriptive analysis of the spatial distribution categorized the AIDS epidemic data from these six-time nodes into five grades. The central and eastern regions of Shandong Province, particularly the surrounding areas centered around Jinan and Qingdao, emerged as the areas most severely affected by the AIDS epidemic. The incidence of AIDS in Shandong Province generally exhibited a decreasing trend from east to west, as depicted in Fig. 2. The spatial distribution map of the average number of AIDS cases in Shandong Province from 2012 to 2022 (Fig. S1) corroborates this observation, highlighting Jinan and Qingdao as regions with high concentration, consistent with the findings in Fig. 2. Conversely, Dongying, Rizhao, and Zaozhuang reported a small average number of cases, displaying a banded distribution from southwest to northeast, aligning with the spatial distribution of incidence.

Results from spatial clustering analysis of HIV/AIDS

Utilizing the HIV incidence data in Shandong Province spanning from 2012 to 2022, the Moran's I corresponding to the HIV epidemic was computed at six time points, derived from the outcomes of the global autocorrelation test. The Moran's I values for HIV incidence in Shandong Province from 2012 to 2022 hovered around 0, with Z-values falling within the range of -1.96 to 1.96. This suggests a random distribution of the epidemic during this period (Table 1). The outcomes of the local autocorrelation test revealed that from 2016 to 2022, Yantai consistently exhibited a "high-high" cluster of AIDS epidemic, with Yantai and its surrounding areas constituting

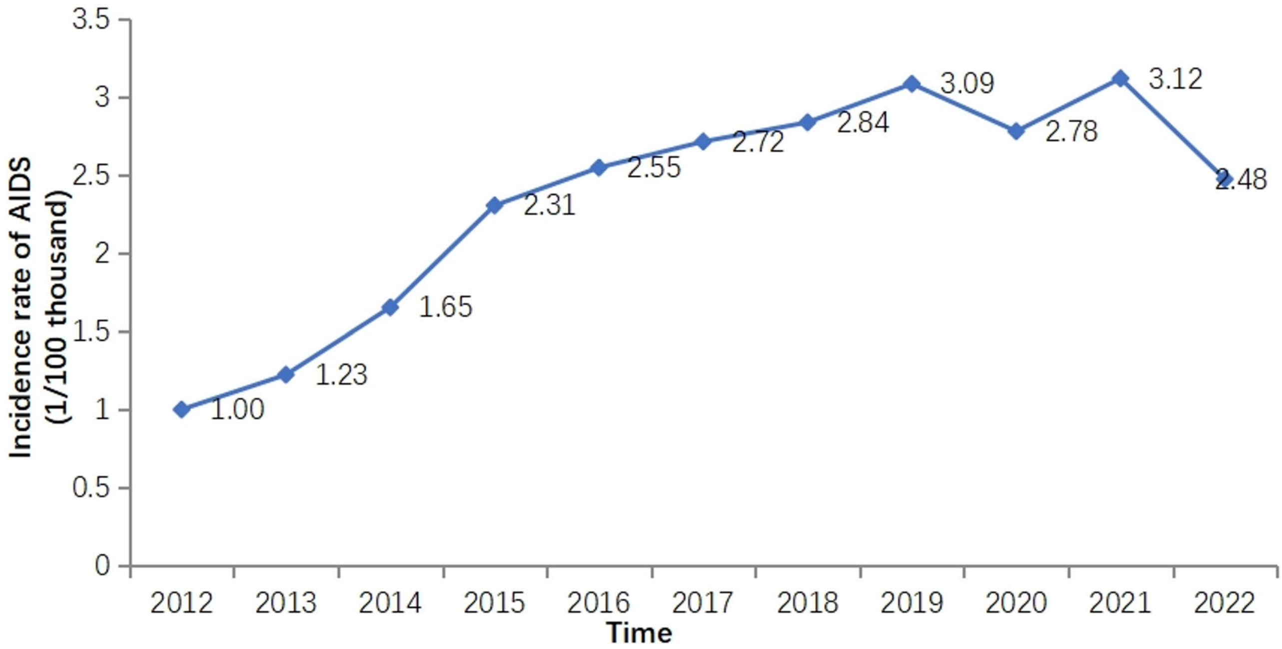

Fig. 1. Trend in the incidence of AIDS in Shandong province from 2012 to 2022. Notes: The unit is per 100 thousand.

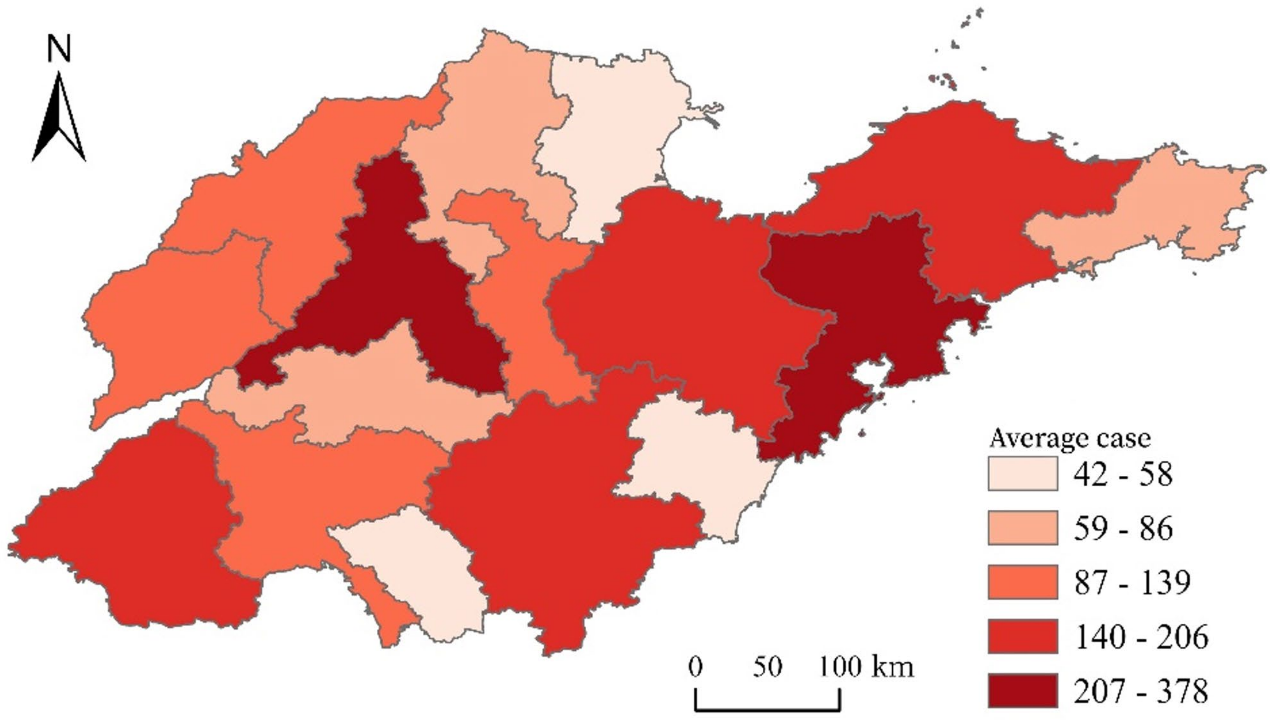

Fig. 2. Distribution of HIV/AIDS incidence in 16 cities across Shandong province from 2012 to 2022. Notes: The unit is per 100 thousand. Self-made maps, production software: ArcGIS 10.3 version, copyright No. SO20160505006.

stable high-value epidemic regions. Conversely, from 2014 to 2022, the occurrence of "low and low" epidemic clusters was limited and remained stable (Fig. 3).

The spatial and temporal scanning analysis of HIV/AIDS in Shandong Province spanning from 2012 to 2022 reveals a non-random spatial and temporal distribution, indicating a noticeable aggregation. The analysis results,

Year	Moran's I	Z-value	*P*-value
2012	0.05	0.598	0.55
2013	0.047	0.558	0.577
2014	0.236	1.402	0.161
2015	− 0.184	− 0.557	0.578
2016	0.032	0.442	0.659
2017	− 0.006	0.276	0.783
2018	− 0.008	0.271	0.786
2019	0.004	0.326	0.745
2020	0.103	0.935	0.350
2021	0.056	0.569	0.570
2022	0.108	0.785	0.432

Table 1. Moran's *I* of HIV/AIDS incidence in Shandong province, 2012–2022.

presented in Table S1, highlight the presence of eight aggregation areas over the past decade, encompassing seven first-level aggregation areas. The central point of aggregation is Dongying City, with an aggregation radius of 188.03 km, occurring during the period from 2017 to 2021 (LLR = 700.869, $P < 0.001$). Additionally, there is one secondary aggregation area identified in Linyi City in 2021 (LLR = 8.748, $P = 0.031 < 0.05$).

Analysis of influencing factors of HIV/AIDS epidemic in Shandong province based on spatial regression

Utilizing a Geographical Weighted Regression (GWR) model, this study explores the influencing factors of the HIV/AIDS epidemic in Shandong Province. The preliminary selection of macro influencing factors involved seven variables: per capita GDP (X1), proportion of tertiary industry GDP (X2), population density (X3), highway mileage (X4), number of beds in health institutions per thousand population (X5), urbanization rate (X6), and medical and health institutions (X7). The variance inflation factor values for each index were calculated using the Ordinary Least Squares (OLS) model. After eliminating per capita GDP and urbanization rate to address multicollinearity, five variables remained. The fixed kernel type was chosen, and the AIC information criterion determined the kernel's scope. Results indicate that the proportion of tertiary industry GDP, number of beds in 1,000 health institutions, population density, highway mileage, and the number of medical and health institutions exhibit notable spatial differentiation characteristics. The spatial visualization of the regression coefficient results (Fig. 4) reveals that the proportion of tertiary industry GDP's coefficient increases from west to east (Fig. 4a), population density's coefficient decreases from west to east (Fig. 4b), highway mileage's coefficient decreases from west to east (Fig. 4c), the number of beds in 1,000 health institutions' coefficient increases from west to east (Fig. 4d), and the coefficient for the number of health care facilities increases from west to east (Fig. 4e). The influence intensity of each factor, ranked from high to low, is as follows: proportion of tertiary industry GDP, number of beds in 1,000 health institutions, population density, highway mileage, and the number of medical and health institutions.

The spatial distribution characteristics of the AIDS epidemic in Shandong Province, as derived from the analysis of influencing factors using geographic detectors, result from the collaborative influence of multiple factors. Employing the natural break point method, data from five variables were discretized into 2 to 8 categories. Considering both the statistical P-value test and the maximum q value, the optimal data discretization scheme was chosen for converting the data into quantifiable types and participating in the calculations, as presented in Table 2. The q values for each single factor and the q values for the combination of two factors after superposition were calculated and compared. The outcomes reveal that the influence of any two influencing factors exhibits either double-factor enhancement or nonlinear enhancement when interaction occurs between them. Specifically, per capita GDP and highway mileage, population density and highway mileage, number of health institution beds per thousand population, and highway mileage, urbanization rate and number of medical and health institutions all demonstrate instances of nonlinear enhancement.

Prediction of the number of HIV/AIDS cases in Shandong province based on the ARIMA model

The prediction was conducted based on the reported AIDS cases. Over the past decade, the HIV/AIDS epidemic in Shandong Province exhibited an initial increase followed by a subsequent decline. Predictive modeling for the epidemic's development was carried out using the ARIMA model. Analysis of the original data's time series, assessed through the Augmented Dickey-Fuller (ADF) unit root test, revealed non-stationarity. After preprocessing, it was observed that the first-order difference tended to stabilize, and the sequence correlation diagram was generated (Fig. S2). Subsequently, considering the Autocorrelation Function (ACF) and Partial Autocorrelation Function (PACF) diagrams, an ARMA (p, q) model was contemplated, where p represents the AR order and q denotes the MA order. Using the provided sequence correlation table, an ARMA model was constructed, and the orders of AR and MA were determined through the Partial Autocorrelation Function (PAC) and Autocorrelation Function (AC) analyses. The preliminary determination suggested an AR model order of 1 or 2 and an MA model order of 2.

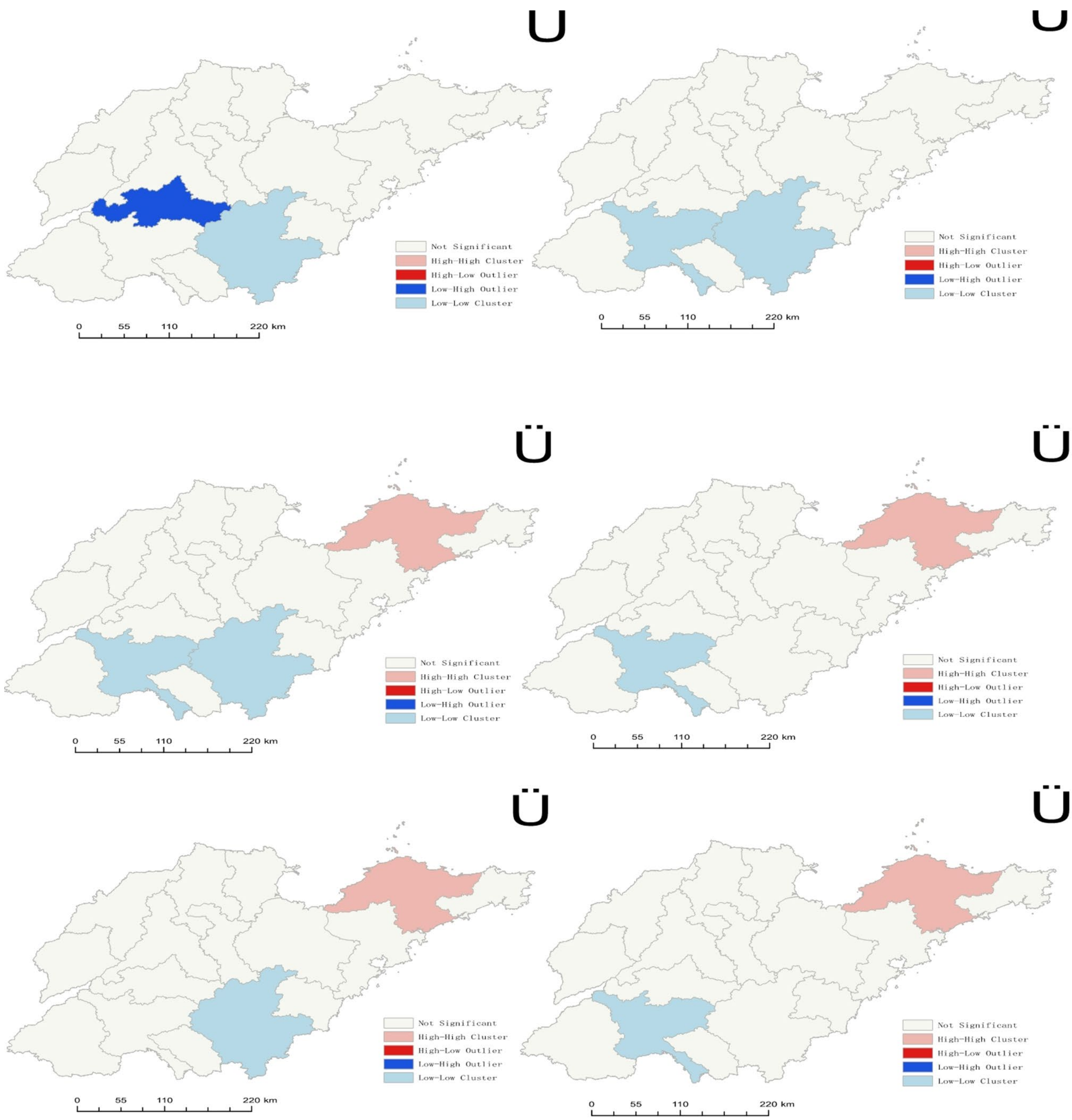

Fig. 3. Distribution of HIV/AIDS epidemic in Shandong province in 2012, 2014, 2016, 2018, 2020, 2022. Notes: Self-made maps, production software: ArcGIS 10.3 version, copyright No. SO20160505006.

In model construction, various considerations come into play, including the examination of autocorrelation and partial autocorrelation functions of residuals, the model's fitting degree, and information criteria such as AIC and BIC. Smaller values for AIC and BIC criteria indicate a better model fit. It is evident that the AIC value for the ARIMA (2,1,2) model is slightly lower than that of the ARIMA (2,1,1) model, with a similar trend observed in the BIC value. This suggests that the ARIMA (2,1,2) model may be a preferable choice under the AIC and BIC criteria. The true and fitted values, along with residuals from January 2012 to December 2022, are depicted in Fig. S3. The R-square value for the model fitting was 0.831, with MAE = 0.2413, RMSE = 0.337, and MAPE = 14.06%. Notably, the residual of the model resembled a white noise sequence, indicating a well-fitted model with a good overall performance.

Applying the same method and procedures, the number of predicted AIDS cases in each city of Shandong Province for the year 2023 is presented in Table S2. As indicated by the results, there is an overall downward trend in AIDS cases within Shandong Province.

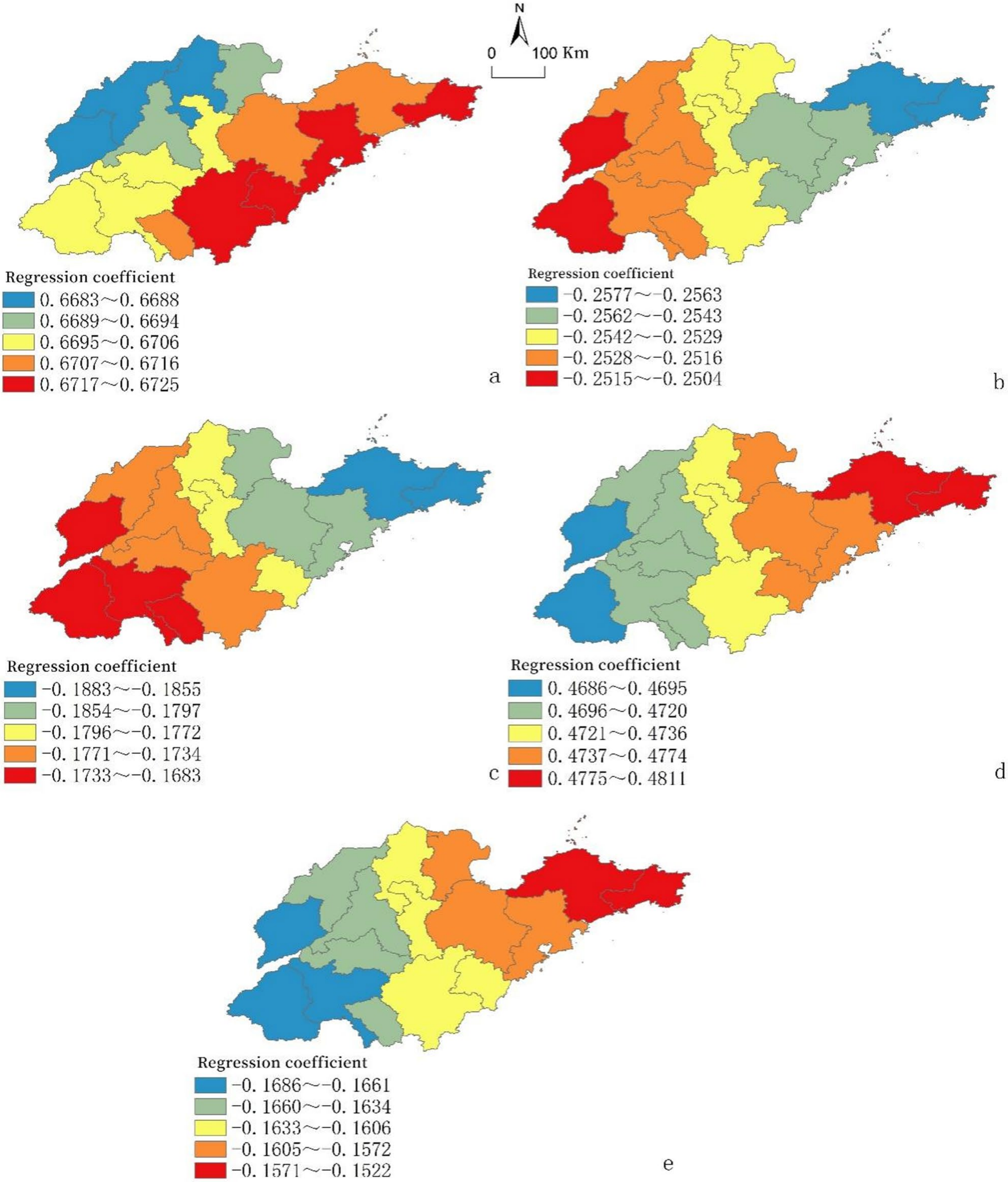

Fig. 4. Spatial differentiation of HIV/AIDS epidemic factors in Shandong province. Notes: Figure 3a and e show the weighted regression coefficients for the proportion of tertiary industry GDP, population density, highway mileage, number of beds in 1,000 health institutions, and number of health care facilities, respectively. Self-made maps, production software: ArcGIS 10.3 version, copyright No. SO20160505006.

Influencing factor	GDP per capita (Yuan)	Proportion of tertiary industry GDP (%)	Population density (people /km²)	Highway mileage (km)	Number of beds in health institutions for 1000 people (per unit)	Urbanization rate (%)	Medical and health institutions (PCS)
GDP per capita (Yuan)	0.749*						
Proportion of tertiary industry GDP (%)	0.958	0.741**					
Population density (people /km²)	0.977	0.889	0.339**				
Highway mileage (km)	0.995	0.892	0.927	0.245**			
Number of beds in health institutions for 1,000 people (per unit)	0.802	0.772	0.985	0.818	0.13**		
Urbanization rate (%)	0.840	0.936	0.986	0.996	0.827	0.748*	
Medical and health institutions (PCS)	0.852	0.962	0.925	0.926	0.8070	0.971	0.611**

Table 2. Results of analysis of geographical detectors. * is $p < 0.05$; ** is $p < 0.01$.

Years	Predicated incidence rate	95% CI	Std error of forecast
2023	4.26	(3.36, 5.16)	0.46
2024	4.56	(3.54, 5.57)	0.52
2025	4.85	(3.74, 5.96)	0.57
2026	5.15	(3.95, 6.35)	0.61
2027	5.44	(4.16, 6.72)	0.65
2028	5.74	(4.38, 7.10)	0.69
2029	6.04	(4.61, 7.47)	0.73
2030	6.33	(4.83, 7.83)	0.77

Table 3. Prediction of incidence rate of AIDS in Shandong province, from 2023–2030. The unit is per 1000 thousand.

Prediction of the incidence of AIDS in Shandong province

This study conducted a forecast of the AIDS incidence in Shandong Province from 2023 to 2030. As depicted in Table 3, the projected AIDS incidence rate in Shandong Province is expected to rise from 4.26 in 2023 to 6.33 in 2030. The prediction suggests an upward trajectory in the incidence of AIDS within Shandong Province from 2023 to 2030.

Discussion

From 2012 to 2022, the incidence of AIDS in Shandong Province exhibited a pattern of initial increase followed by a subsequent decrease. Notably, the central and eastern regions of Shandong Province reported relatively higher incidences of AIDS, and these spatial differences are influenced by various contributing factors. The forecast for the period from 2023 to 2030 indicates a predicted increase in the incidence of AIDS in Shandong Province.

The AIDS incidence rate in Shandong Province witnessed an increase from 2012 to 2019. China's implementation of various HIV testing strategies and the exponential growth of voluntary counseling and testing sites contributed to the rise in HIV detection during this period[22,23]. Additionally, mandatory HIV testing in most hospitals during treatment further fueled an increase in HIV diagnoses[15]. However, from 2020 to 2022, the incidence of AIDS in Shandong Province demonstrated an overall decreasing trend. This decline may be attributed to measures implemented during the COVID-19 pandemic, such as restrictions on gathering size, public transport closures, and home isolation, which discouraged individuals living with AIDS from seeking medical care and led to a decrease in positive detection rates[24]. The study's prediction for the AIDS incidence in Shandong Province from 2023 to 2030 reveals an increasing trend, with an expected incidence of 6.33 in 2030. Despite the United Nations Sustainable Development Goals aiming to end the AIDS epidemic by 2030[25]. the prediction suggests that AIDS in Shandong Province continues to exhibit an increasing trend, highlighting a significant gap from the 2030 target. The government should play an active role in organizing and coordinating efforts, with all sectors taking responsibility for AIDS prevention and treatment in Shandong Province. Focused efforts should center on controlling the source of infection, interrupting the means of transmission, and safeguarding vulnerable groups. Achieving the goal of ending the AIDS epidemic by 2030 is crucial for the protection of public health and should be pursued expeditiously.

The HIV infection rate in Shandong Province exhibits a heightened spatial distribution in the central and eastern regions, particularly in Jinan, Qingdao, and their surrounding areas, marking this region as the most severely affected by the HIV/AIDS epidemic. This observation aligns with previous research findings[26]. The spatial expansion of the AIDS epidemic in Shandong Province is continuous and demonstrates a certain degree of clustering. This regional disparity can be attributed to the combined influences of natural and human environments[27,28]. The central and eastern regions of Shandong Province boast high population density, and the efficient transportation infrastructure facilitates significant population mobility, thereby accelerating the spread of HIV/AIDS cases[12,29]. Areas with a substantial share of tertiary GDP are associated with a higher level of service sector development, an elevated risk of commercial sex, and a propensity for drug use, all contributing factors to the spread of AIDS[30]. Moreover, the east-central part of Shandong Province is abundant in healthcare resources, fostering higher awareness of voluntary testing among residents and resulting in a relatively high HIV detection rate[12], thereby prone to spatial aggregation. Conversely, in the western part of Shandong Province, inadequate healthcare resource allocation may lead to a scenario where HIV-infected individuals remain chronically infected but unaware of their condition.

The factors influencing the incidence of HIV are complex and varied, and there are differences in the intensity and spatial variation in the effects of the influencing factors. From the results of geographical weighted regression analyses in this study, it can be seen that the proportion of tertiary industry GDP, number of beds in 1,000 health institutions, population density, highway mileage, and the number of medical and health institutions decreases in order. This result is consistent with the results of a previous study[31]. Study shows commercial sex workers play key role in spreading HIV and STDs[32]. A study in China found that improved medical care reports more HIV infections, and ease of transport facilitates the movement of people and the flow of drugs, which also accelerates the spread of the disease[33].

This study possesses several notable strengths. Firstly, the utilization of AIDS incidence data spanning from 2012 to 2022 in Shandong Province ensures a sufficiently long time frame, enhancing the robustness of the predicted AIDS incidence results. Secondly, there is a scarcity of comprehensive studies addressing the spatial distribution, evolutionary trends, and incidence rate prediction of AIDS in Shandong Province. This study fills this gap by providing a thorough and integrated analysis. Third, this study used spatial autocorrelation modelling and spatio-temporal scanning analyses to combine both temporal and spatial dimensions in describing the HIV epidemic in Shandong province, taking into account both spatial clustering and temporal patterns, allowing for analyses that provide a more comprehensive understanding of the distribution of events over time[34]. The influencing factors were also analysed using geographically weighted regression and geoprobe models to improve fitting accuracy and reveal local relationships while taking into account spatial heterogeneity[35]. Lastly, the application of the ARIMA model for prediction in this study enables effective control over potential confounding factors, contributing to a more accurate prediction. In conclusion, this study holds reference significance for the future development of AIDS prevention and treatment strategies and measures in Shandong Province.

There are several limitations to our study. Firstly, the analysis focused solely on the specific region of Shandong Province, resulting in a relatively limited scope for the study. Secondly, the prediction of AIDS incidence in Shandong Province relied on a single model, preventing the comparison of results to select the optimal predictive model. Thirdly, due to impact of COVID19, we removed HIV incidence data for 2020, 2021, and 2022 from our prediction, which could potentially bias and influence the results. In addition, Our study did not use a spatiotemporal model, so it could not take into account the interaction effects of space and time. Future research should consider introducing a spatiotemporal model while considering the dependence and heterogeneity of space and time. Lastly, the presence of data gaps hindered the comparison of various population characteristics and prevented a comparison between the HIV-susceptible population and the general population.

In order to effectively curb the further spread of AIDS, the relevant health authorities should widely publicise the dangers of AIDS, the means of transmission and effective preventive measures throughout society, help the public to correctly understand AIDS, and expeditiously achieve the United Nations goal of ending AIDS by 2030. Relevant authorities in Shandong Province should focus on high-risk groups and high-prevalence areas to effectively control the spread of the epidemic. In addition, the Government should continue to strengthen the monitoring of AIDS throughout the country and, in the light of the regional differences in AIDS in Shandong Province, formulate effective and feasible regional AIDS prevention and control strategies and measures, rationally allocate resources for prevention and treatment, and reduce the incidence of AIDS.

Conclusion

The incidence of AIDS exhibited a rising trend followed by a subsequent decline in Shandong Province in China from 2012 to 2022. The prediction suggests that the incidence of AIDS in Shandong Province will continue to increase from 2023 to 2030. Particularly, the central and eastern regions of Shandong Province, notably Jinan and Qingdao, are facing serious AIDS epidemics. Given the critical situation of AIDS in Shandong Province, local governments should intensify comprehensive prevention and treatment efforts and strengthen the publicity of AIDS prevention and treatment in the whole society. The relevant departments also need to do a better job of screening for AIDS, and take timely intervention measures for high-risk groups and areas with a high prevalence of AIDS, so as to reduce the incidence of the disease. As China is the largest developing country, future research should build on this study and be extended to the whole country and other developing countries in order to achieve the goal of ending AIDS globally by 2030.

Data availability

The data that support the findings of this study are available upon request from the authors.

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Declarations

Competing interests
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