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Healthcare access, care substitution and population retention in rural China: the labour-allocation effect of public services

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Abstract

Rural public services are commonly expected to enhance place attractiveness and strengthen population retention. This study examines a further possibility: improvements in local healthcare may also ease household caregiving constraints and expand the employment and mobility options available to working-age family members. Using a balanced panel of 157 county-level units in Henan Province, China, from 2010 to 2022, the study investigates the relationship between healthcare access and population retention using county fixed-effects estimation, mediation and moderation analyses, and spatial econometric models. Healthcare access increased substantially over the study period, while population retention declined overall. Meanwhile, the coupling coordination degree between the two indices increased, revealing a pattern of apparent coordination. The fixed-effects estimates show a statistically significant negative average association between healthcare access and population retention. Mediation results are consistent with the proposed care-substitution pathway: healthcare access is positively associated with county-level care-substitution capacity, which is negatively associated with population retention. The estimated indirect component accounts for 53.1% of the total association within the mediation specification. Higher infrastructure connectivity attenuates the negative association. Regional analyses show a statistically significant negative association in southern Henan and a statistically significant positive association in central Henan. Spatial Durbin estimates show negative average indirect effects under all four spatial weight matrices, with statistical significance only under the inverse-squared geographical-distance matrix with a 200-km threshold. The study develops the concept of the labour-allocation effect of public services to interpret these relationships,

complementing conventional accounts of welfare and place attractiveness with attention to household care constraints, employment opportunities and regional labour-market connections.

Keywords: Rural depopulation; Healthcare access; Care substitution; Household labour allocation; Population retention; Local employment absorption; Spatial spillovers

1 Introduction

Rural depopulation is reshaping communities in many parts of the world, often through the selective out-migration of working-age residents and the ageing of those who remain (Thissen et al., 2010; Søder and Nielsen, 2025). These demographic changes affect local labour supply, intergenerational support and the sustainability of essential services (Alonso et al., 2023). In China, rural population decline has coincided with continued improvements in basic public services, including county-level healthcare provision (Yin et al., 2026; Xia and Fang, 2025). Henan Province illustrates the divergence between these trends: from 2010 to 2022, its mean county-level healthcare access index increased markedly, while the mean population retention index declined overall. This contrast raises a central question for rural development research: how can improving healthcare access coexist with declining population retention?

Research on public services and population mobility has largely examined how service provision influences residential choices and the attractiveness of places. Building on Tiebout's (1956) framework, this literature recognises public services as an important feature of local living conditions and population distribution. Empirical studies in China likewise

show how healthcare, education and other public services, alongside employment opportunities, shape migration and settlement decisions (Xia and Lu, 2015; Liu et al., 2025). Research on small towns and shrinking rural regions further highlights the importance of essential services for rural livelihoods and local development (Yu et al., 2023; Christiaanse, 2025). While these studies establish the welfare and place-attraction functions of public services, less attention has been paid to how improvements in services at places of origin affect household responsibilities that constrain labour mobility. This household dimension is particularly relevant in rural communities, where care for dependent relatives can shape employment and migration decisions.

The New Economics of Labour Migration views migration as part of household strategies for allocating labour, diversifying income and managing risk, rather than solely as an individual response to wage differences (Stark and Bloom, 1985; Taylor, 1999). In rural China, the care needs of older relatives can require working-age family members to remain locally available, limiting their employment and migration choices (Giles and Mu, 2007). Research on formal and informal care shows that external services can substitute for certain forms of assistance traditionally provided within families (Charles and Sevak, 2005; Bonsang, 2009; Sun et al., 2023). Improved access to local healthcare may similarly reduce the need for adult children to accompany older relatives to medical appointments, assist with treatment and remain available for health-related care. The direct beneficiaries of healthcare can thus differ from the working-age relatives whose employment choices respond to changes in care requirements. We refer to this broader capacity of public services to reshape household constraints and influence the allocation of labour across activities and places as the

labour-allocation effect of public services.

The implications of this greater labour-allocation flexibility for rural population retention depend on employment opportunities within and beyond the county. Where local non-farm jobs are scarce and external labour markets offer higher returns, households have stronger incentives to allocate working-age members to employment elsewhere (Stark and Taylor, 1991; Xia and Lu, 2015). Stronger local employment opportunities, by contrast, can support labour retention within the county (Stockdale, 2006; Zhang and Mu, 2026). Infrastructure connectivity further shapes these choices by facilitating movement across county boundaries while improving local market access and employment conditions (Wang and Ma, 2019). Household labour allocation is also embedded in wider regional systems that connect counties through labour markets, transport networks and cross-county healthcare use. Improvements in one county's healthcare provision may therefore be associated with population retention in surrounding counties.

As a major agricultural and labour-exporting province, Henan provides a relevant setting for examining these relationships, with considerable variation across counties in healthcare provision, economic conditions and population retention. Using a balanced panel of 157 county-level units from 2010 to 2022, this study examines the association between healthcare access and population retention and investigates the proposed care-substitution pathway using a county-level index of care-substitution capacity. It also assesses how this association varies with infrastructure connectivity and regional conditions and whether it extends across county boundaries. Healthcare access and population retention are measured using entropy-weighted composite indices. Temporal and spatial analyses, including a descriptive coupling

coordination assessment, characterise their evolution. County fixed-effects estimation, mediation and moderation analyses, spatial Durbin models and robustness checks are then used to examine the proposed relationships.

This study makes three contributions to research on public services and rural population change. First, it extends place-based perspectives on public services by incorporating household labour allocation into explanations of their demographic consequences, alongside welfare and local attractiveness. Second, it connects research on care substitution with the New Economics of Labour Migration, developing an intergenerational perspective on how healthcare provision can shape working-age family members' employment options through changes in caregiving responsibilities. Third, it situates this household perspective within uneven local employment opportunities and interconnected regional labour markets. By examining infrastructure connectivity, regional heterogeneity and spatial dependence, the study explores how the healthcare–retention association varies across local and regional contexts. Together, these contributions bring public-service provision, household responsibilities and spatially differentiated employment opportunities into a common framework for understanding rural population change.

2 Conceptual framework and hypotheses

This study develops a conceptual framework centred on household labour allocation to examine the relationship between healthcare access and county-level population retention (Fig. 1). The framework comprises two linked household processes. First, improved access to local healthcare may reduce families' reliance on certain forms of health-related assistance from relatives, easing caregiving constraints on working-age members. Second, greater

flexibility may widen households' choices among agricultural production, local non-farm employment and out-of-county work. Whether these choices support continued residence depends on employment opportunities within and beyond the county. Infrastructure connectivity further shapes these choices by facilitating access to external labour markets while improving conditions for local employment. Regional labour markets and healthcare service networks also connect household decisions across county boundaries. Together, these processes and contextual conditions underpin the proposed care-substitution pathway, the conditional nature of the healthcare–retention relationship and its potential spatial spillovers, providing the basis for the four hypotheses developed below.

2.1 Household labour allocation and population retention

Households allocate labour across activities and locations by balancing expected employment returns with family responsibilities. In rural China, the health and care needs of older relatives may require working-age family members to remain locally available, even when employment elsewhere offers higher returns (Ettner, 1995; Bolin et al., 2008; Giles and Mu, 2007). These place-bound caregiving obligations narrow the range of employment choices that households can realistically pursue: opportunities offering greater economic rewards may remain impractical when regular family care is required. Household labour allocation therefore reflects the interaction between economic incentives and the need to maintain intergenerational support (Stark and Taylor, 1991; Shi and Yang, 2012).

Improved healthcare access may alter this balance by reducing the need for working-age relatives to remain continuously available for family care, thereby widening the employment options households can feasibly pursue. Whether this flexibility translates into lower

population retention depends on local and external employment opportunities and the form of labour mobility involved. Where local non-farm jobs are scarce and earnings elsewhere are higher, households may favour out-of-county employment (Xia and Lu, 2015). Such employment is more likely to weaken population retention when it involves prolonged absence or relocation rather than cross-county commuting. Stronger local employment opportunities, by contrast, can support both labour participation and continued residence within the county (Stockdale, 2006; Zhang and Mu, 2026). Improved healthcare may also enhance local welfare and place attractiveness. The overall healthcare–retention association thus reflects the balance between these place-based benefits and expanded opportunities for employment elsewhere.

In an agricultural and labour-exporting province such as Henan, higher returns from work outside the county can provide incentives for relocation, although non-farm employment opportunities vary across counties. In this context, the outward labour allocation made more feasible by improved healthcare access may, on average, outweigh its contribution to local welfare and place attractiveness. This provides a basis for expecting a negative average association between healthcare access and county-level population retention, while allowing its strength to vary with local economic conditions. Accordingly, this study proposes the following hypothesis:

H1: Higher healthcare access is associated, on average, with lower population retention within counties.

2.2 Care substitution and labour reallocation

Care substitution concerns the redistribution of specific caregiving tasks between families and external service providers. Research on formal and informal care shows that external services can take over certain forms of practical assistance traditionally supplied by family members (Charles and Sevak, 2005; Bonsang, 2009). Evidence from China similarly indicates that home-based eldercare services can reduce older adults' reliance on certain forms of instrumental support from adult children (Sun et al., 2023). Applied to healthcare, this task-based perspective suggests that access to local medical services may lessen some health-related demands on working-age family members.

In rural China, improved access to local healthcare may reduce the time adult children spend accompanying older relatives to medical appointments and assisting with treatment, as well as the need to remain nearby for health-related contingencies. This change has an intergenerational dimension: older relatives benefit directly from healthcare provision, while working-age family members may gain greater flexibility in their employment and location choices. As place-bound caregiving obligations ease, households can adjust labour allocation among agricultural production, local non-farm employment and out-of-county work. Where external labour markets offer higher returns, some working-age members may take up employment and reside outside their home county for extended periods, potentially contributing to lower population retention (Stark and Taylor, 1991; Xia and Lu, 2015).

At the county level, care-substitution capacity provides an empirical representation of the external service conditions that may ease household caregiving constraints. It reflects the availability of healthcare and welfare facilities, together with supporting infrastructure that facilitates access to these services. Greater healthcare access is expected to be associated with

stronger care-substitution capacity. These conditions may, in turn, reduce the need for working-age relatives to remain locally available for family care and broaden their employment options. Where external employment offers higher returns and involves relocation, stronger care-substitution capacity may consequently be associated with lower county-level population retention. This reasoning leads to the following hypothesis:

H2: Higher healthcare access is associated with greater care-substitution capacity, which in turn is associated with lower population retention.

2.3 Infrastructure connectivity and conditional labour allocation

The availability of local non-farm employment shapes whether greater household labour-allocation flexibility supports continued residence or encourages relocation. Manufacturing and service-sector jobs can provide alternatives to employment elsewhere, while limited local opportunities may increase the appeal of out-of-county work (Stockdale, 2006; Zhang and Mu, 2026). Infrastructure connectivity further influences these choices by shaping access to both local and external labour markets.

Infrastructure connectivity may moderate the healthcare–retention association through two competing channels. First, stronger transport and information links can reduce the financial, temporal and informational costs of accessing employment beyond the county. Where greater labour-allocation flexibility enables longer-term relocation, improved connectivity may strengthen the negative healthcare–retention association. Second, connectivity can improve market access, reduce transaction costs and create more favourable conditions for non-farm economic activity and firm location (Wang and Ma, 2019). It may also broaden access to

nearby jobs through commuting without requiring workers to change their county of residence. Where these opportunities support continued residence within the home county, infrastructure connectivity may instead attenuate the negative association.

These competing channels suggest that infrastructure connectivity may either strengthen or attenuate the negative association between healthcare access and population retention, depending on the relative importance of outward mobility and employment opportunities compatible with continued residence. Accordingly, this study proposes the following hypothesis:

H3: Infrastructure connectivity moderates the association between healthcare access and population retention, with the direction of moderation depending on the relative strength of outward-mobility facilitation and local employment absorption.

2.4 Spatial embeddedness and regional spillovers

Household labour allocation is embedded in regional networks connecting counties through labour markets, transport infrastructure and healthcare services. Rural households may organise employment and care arrangements across administrative boundaries: working-age family members may work outside their home county, while older relatives may seek medical treatment elsewhere. Improved healthcare access in one county may therefore expand care options for households in neighbouring counties and alter the caregiving constraints shaping their employment and residence decisions. These cross-boundary connections provide a basis for examining the association between healthcare access in one county and population retention in surrounding counties.

Two cross-county channels may give rise to such associations. First, shared migration and recruitment networks may transmit changes in labour-allocation opportunities across counties. Where improved healthcare access enables working-age residents of one county to pursue employment farther afield, their participation in these networks may also facilitate access to external jobs for households in neighbouring counties. If such opportunities encourage prolonged relocation to employment centres beyond the connected counties, population retention may decline across the wider area. Second, residents of neighbouring counties may use medical services in counties with better healthcare provision, potentially easing health-related caregiving obligations within their households. Where this greater flexibility enables working-age relatives to work and reside elsewhere for extended periods, population retention in neighbouring counties may also decline.

The geographical reach of these relationships depends on both proximity and the strength of regional labour-market and healthcare-service connections. Stronger employment and service ties may be associated with greater spatial interdependence, but these ties are not determined by geographical distance alone. Consequently, the proposed negative association between healthcare access in one county and population retention in surrounding counties may vary in magnitude across spatial scales. This reasoning leads to the following hypothesis:

H4: Higher healthcare access in a county is associated with lower population retention in surrounding counties, with the strength of this association varying across spatial scales.

3 Study area, measures and empirical strategy

3.1 Study area and data

Henan Province, a major agricultural region and source of migrant labour in central China, provides a suitable setting for examining the relationship between healthcare access and population retention. During the study period, county-level healthcare provision expanded substantially amid extensive labour mobility and varying local economic conditions. The geographical location of the study area is shown in Fig. 2.

The study draws on a balanced panel of 157 county-level units in Henan Province covering the period 2010–2022. Consistent with the statistical coverage of the China County Statistical Yearbook, the sample comprises counties, county-level cities and selected municipal districts with comparable administrative functions. Administrative divisions were harmonised across the study period to maintain consistent geographical units, resulting in 2,041 county-year observations.

Data were compiled from the *China County Statistical Yearbook*, *Henan Statistical Yearbook*, *Henan Survey Yearbook*, statistical yearbooks of prefecture-level cities in Henan, and official statistical communiqués. Occasional missing values were imputed using linear interpolation, and continuous variables were winsorised at the 1st and 99th percentiles to reduce the influence of extreme observations.

The main analyses use the full panel of 157 county-level units. For the regional heterogeneity analysis, the 35 municipal districts are excluded to focus on counties and county-level cities, yielding a subsample of 122 units and 1,586 county-year observations.

3.2 Measures

3.2.1 Healthcare access

The principal explanatory variable is a composite index of county-level healthcare access, constructed from two dimensions: healthcare resources and economic access (Penchansky and Thomas, 1981). The healthcare-resource dimension comprises beds in hospitals and township health centres, health technical personnel and practising physicians, reflecting local healthcare capacity and the availability of medical professionals. The economic-access dimension includes per capita disposable income of rural residents, local general budget expenditure and household savings deposits, capturing household financial capacity and the broader fiscal conditions associated with access to healthcare.

All six indicators are positively oriented and normalised using the min–max method. Entropy weights are calculated from the pooled county-year panel, providing a consistent weighting scheme across the study period. The standardised indicators are then aggregated into a composite healthcare access index using these weights. Higher index values indicate greater healthcare resource availability and more favourable economic and fiscal conditions. The indicators and their corresponding weights are presented in Table 1.

3.2.2 Population retention

The dependent variable is a composite index of county-level population retention, comprising three dimensions: population stock, labour-force structure and socioeconomic vitality. Population stock is measured by year-end total population, rural population and registered population, reflecting the size of the local population base. The labour-force structure dimension includes rural employment, employment in agriculture, forestry, animal husbandry

and fisheries, and year-end employment in tertiary-sector establishments, capturing employment levels across different sectors. Socioeconomic vitality is measured by primary-school enrolment, mobile telephone subscriptions and total retail sales of consumer goods, reflecting the scale of local social and economic activity.

All nine indicators are positively oriented and standardised before aggregation using the entropy-weighting method. The resulting population retention index combines measures of population size, employment and socioeconomic activity, with higher values indicating a larger population and employment base and a higher level of local socioeconomic activity. The indicators and their corresponding entropy weights are presented in Table 1.

Table 1. Indicator system and entropy weights for healthcare access and population retention

Index	Dimension	Indicator	Unit	Direction	Entropy weight
Healthcare access	Healthcare resources	Hospital and township-health-centre beds	beds	+	0.17725957
		Health technical personnel	persons	+	0.15548388
		Practising physicians	persons	+	0.12945782
	Economic access	Rural disposable income per capita	CNY	+	0.12573715
		Local general budget expenditure	10,000 CNY	+	0.18209942
		Household savings deposits	10,000 CNY	+	0.22996217
Population retention	Population stock	Year-end total population	10,000 persons	+	0.0862
		Rural population	10,000 persons	+	0.0933
		Registered population	10,000 persons	+	0.0933
	Labour-force structure	Rural employed population	persons	+	0.0849
		Employment in agriculture, forestry, animal husbandry and fisheries	persons	+	0.0997
		Employees in tertiary-sector units at year-end	persons	+	0.1540
	Socioeconomic vitality	Primary-school enrolment	persons	+	0.1303
		Mobile telephone subscriptions	subscriptions	+	0.0557
		Total retail sales of consumer goods	10,000 CNY	+	0.1966

Notes: *All indicators are positively oriented. Entropy weights are calculated from the county-level panel data. CNY denotes Chinese yuan.*

3.2.3 Care-substitution capacity, infrastructure connectivity and controls

The mediating variable is the care-substitution capacity index, which reflects local service resources and transport conditions that support alternatives to care provided within the household. The index comprises three indicators: welfare beds per capita, hospital and township-health-centre beds per capita, and road-network density. These indicators are standardised and combined using an unweighted arithmetic mean to construct the county-level care-substitution capacity index.

The moderating variable is infrastructure connectivity (IFI), which reflects local telecommunications and investment conditions associated with labour mobility and regional economic linkages. The index combines telecommunications penetration, measured by the ratio of mobile telephone subscriptions to the rural population, with fixed-asset investment intensity, measured by total fixed-asset investment per unit of administrative land area. IFI is calculated as the natural logarithm of one plus the product of these two ratios.

The analysis also includes three economic control variables: the natural logarithms of gross domestic product (GDP), GDP per capita and secondary-industry value added. These variables account for differences in county economic scale, per capita economic output and the scale of secondary-sector activity, respectively.

3.3 Empirical strategy

To examine the joint evolution of healthcare access and population retention, the coupling coordination degree is calculated using a coupling coefficient and a composite development index. Specifically, $C = 2\sqrt{M \cdot P}/(M + P)$, $T = 0.5M + 0.5P$ and $D = \sqrt{C \cdot T}$, where M

and P represent the healthcare access and population retention indices, respectively; C denotes the coupling coefficient, T the composite development index and D the coupling coordination degree. Temporal trends are examined through descriptive analysis, while the spatial distribution and clustering of healthcare access and population retention are assessed using global Moran's I and local indicators of spatial association (LISA).

To examine the relationship between healthcare access and population retention (H1), a county fixed-effects model is estimated, with the population retention index as the dependent variable and the healthcare access index as the principal explanatory variable. The model controls for the natural logarithms of GDP, GDP per capita and secondary-industry value added. County fixed effects account for time-invariant county characteristics, and standard errors are clustered at the county level. A Hausman test is used to inform the choice between fixed- and random-effects specifications.

The proposed care-substitution pathway (H2) is examined using a three-step mediation approach. The first step estimates the overall association between healthcare access and population retention. The second examines the association between healthcare access and care-substitution capacity, while the third includes both variables in the population retention model. The indirect association is calculated as the product of the estimated pathway coefficients, and its statistical significance is assessed using the Sobel test. Direct and total associations are also reported to characterise the role of the care-substitution pathway in the overall relationship.

To examine the moderating role of infrastructure connectivity (H3), the county fixed-effects model is extended to include an interaction term between healthcare access and infrastructure

connectivity. Both variables are mean-centred before the interaction term is constructed. The marginal association between healthcare access and population retention is then estimated at different levels of infrastructure connectivity to examine how the relationship varies with local infrastructure conditions.

To examine spatial associations across counties (H4), a spatial Durbin model (SDM) is estimated, incorporating spatially lagged dependent and explanatory variables alongside county fixed effects. Four spatial weight matrices are employed: four-nearest-neighbour and six-nearest-neighbour matrices, an inverse-squared geographical distance matrix with a 200-km threshold, and an economic-distance matrix based on differences in counties' average GDP per capita over the study period. Average direct, indirect and total effects are estimated to distinguish within-county associations from those extending across county boundaries (LeSage and Pace, 2009; Elhorst, 2014).

Finally, the robustness of the baseline association is examined using two alternative specifications. First, healthcare access is lagged by one year, resulting in 1,884 county-year observations. Second, year fixed effects are added to the baseline county fixed-effects model to account for common temporal influences across counties. The sensitivity of the spatial estimates is further assessed using alternative spatial weight matrices that capture different forms of inter-county proximity.

3.4 Descriptive statistics

Table 2 presents descriptive statistics for the main variables, based on 2,041 county-year observations. The healthcare access index has a mean of 0.207 and a standard deviation of

0.109, while the population retention index has a mean of 0.279 and a standard deviation of 0.142. Both indices exhibit considerable variation across the sample. Infrastructure connectivity also varies, with a mean of 6.928 and a standard deviation of 1.207. The economic control variables, including the natural logarithms of GDP, GDP per capita and secondary-industry value added, show further differences in economic scale, per capita output and secondary-sector activity across county-level units.

Table 2. Descriptive statistics

Variable	Observations	Mean	Std. dev.	Minimum	25th percentile	Median	75th percentile	Maximum
Healthcare access index	2,041	0.207	0.109	0.023	0.127	0.185	0.256	0.794
Population retention index	2,041	0.279	0.142	0.012	0.165	0.251	0.357	0.839
Infrastructure connectivity index (IFI)	2,041	6.928	1.207	3.547	6.044	6.846	7.768	10.954
GDP, log	2,041	14.568	0.646	12.611	14.136	14.559	14.974	17.299
GDP per capita, log	2,041	10.588	0.531	9.131	10.224	10.591	10.954	12.169
Secondary-industry value added, log	2,041	13.783	0.710	11.477	13.358	13.767	14.234	16.147

Notes: *All continuous variables were winsorised at the 1st and 99th percentiles before estimation. The healthcare access and population retention indices are entropy-weighted composite measures. IFI denotes the infrastructure connectivity index. "Log" denotes the natural logarithm.*

4 Results

4.1 Temporal patterns and apparent coordination

Table 3 and Fig. 3 show contrasting temporal trends in healthcare access and population retention across county-level units in Henan Province between 2010 and 2022. The mean healthcare access index increased steadily from 0.0895 to 0.3351, an increase of approximately 274%, whereas the mean population retention index declined from 0.2908 to

0.2551, a decrease of approximately 12.3%, despite annual fluctuations. The sustained improvement in healthcare access thus coincided with an overall decline in population retention.

Table 3. Annual trends in healthcare access and population retention, 2010–2022

Year	Healthcare access index	Population retention index
2010	0.0895	0.2908
2011	0.1066	0.2928
2012	0.1275	0.2970
2013	0.1475	0.2868
2014	0.1638	0.2643
2015	0.1830	0.2961
2016	0.1996	0.2865
2017	0.2194	0.2131
2018	0.2436	0.2799
2019	0.2688	0.2901
2020	0.2921	0.2947
2021	0.3100	0.2810
2022	0.3351	0.2551
Period mean	**0.2067**	**0.2791**

Notes: *Values are annual means across the 157 county-level units in the balanced panel. The healthcare access and population retention measures are entropy-weighted composite indices.*

The relative positions of the two indices changed over the study period. The population retention index fell to 0.2131 in 2017, recovered to 0.2947 in 2020 and declined again thereafter, while healthcare access increased each year. The healthcare access index first exceeded the population retention index in 2017, but population retention remained higher during 2018–2020. Healthcare access regained the higher position in 2021 and remained above population retention in 2022.

The coupling coordination degree increased overall from 0.3892 in 2010 to 0.5284 in 2022, despite annual fluctuations (Table 4; Fig. 4). Its classification accordingly shifted from moderate disorder to barely coordinated. This improvement in the composite measure

coincided with steadily rising healthcare access and an overall decline in population retention, revealing a pattern of apparent coordination in which the two underlying indices followed contrasting trajectories.

Table 4. Coupling coordination between healthcare access and population retention, 2010–2022

Year	Coupling coordination degree (D)	Coordination category
2010	0.3892	Moderate disorder
2011	0.4073	Near disorder
2012	0.4292	Near disorder
2013	0.4417	Near disorder
2014	0.4432	Near disorder
2015	0.4703	Near disorder
2016	0.4769	Near disorder
2017	0.4529	Near disorder
2018	0.4973	Near disorder
2019	0.5163	Barely coordinated
2020	0.5304	Barely coordinated
2021	0.5309	Barely coordinated
2022	0.5284	Barely coordinated
Period mean	**0.4703**	**Near disorder**

Notes: *D denotes the coupling coordination degree between healthcare access and population retention. Coordination categories follow the classification adopted in this study.*

4.2 Spatial patterns

The spatial distribution of healthcare access across Henan's county-level units changed markedly between 2010 and 2022 (Fig. 5). Initially, low-value areas were concentrated in peripheral counties of western and southern Henan, while high-value counties were relatively scattered. Over time, low-value areas contracted and high-value areas expanded, becoming increasingly concentrated in parts of the central, northern and eastern plains by 2020–2022, while comparatively low levels persisted in some peripheral counties of western and southern Henan.

Population retention exhibited a contrasting spatial pattern (Fig. 6). In 2010, relatively high

values formed contiguous areas across parts of eastern and southern Henan. These high-value areas gradually contracted, particularly in the eastern and central plains, where lower population retention became more widespread by 2020–2022. Meanwhile, some mountainous and peripheral counties continued to exhibit comparatively high retention levels. This changing distribution contrasts with the expansion of higher healthcare access across the plains, highlighting the spatial divergence between the two indices.

Both healthcare access and population retention exhibited positive spatial autocorrelation across the four benchmark years (Tables 5 and 6). For healthcare access, Global Moran's I declined overall from 0.2223 in 2010 to 0.1674 in 2022, with some fluctuations over the intervening years. Population retention showed greater variation, with Moran's I increasing from 0.3080 in 2010 to 0.3239 in 2015, declining to 0.1646 in 2020 and recovering to 0.2555 in 2022. All estimates were statistically significant ($p < 0.001$), indicating spatial clustering of counties with similar index values, although the strength and temporal evolution of clustering differed between the two indices.

Table 5. Global Moran's I for healthcare access

Year	Global Moran's I	Expected I, E[I]	Variance	z-statistic	p-value
2010	0.222349	−0.006410	0.001428	6.052717	<0.001
2015	0.190013	−0.006410	0.001428	5.198752	<0.001
2020	0.202823	−0.006410	0.001428	5.524480	<0.001
2022	0.167429	−0.006410	0.001428	4.597676	<0.001

Notes: *Positive values of global Moran's I indicate positive spatial autocorrelation.*

Table 6. Global Moran's I for population retention

Year	Global Moran's I	Expected I, E[I]	Variance	z-statistic	p-value
2010	0.308020	−0.006410	0.001440	8.286038	<0.001
2015	0.323943	−0.006410	0.001440	8.713741	<0.001
2020	0.164593	−0.006410	0.001440	4.505072	<0.001
2022	0.255503	−0.006410	0.001440	6.895448	<0.001

Notes: *Positive values of global Moran's I indicate positive spatial autocorrelation.*

The local indicators of spatial association (LISA) reveal contrasting changes in the spatial clustering of healthcare access and population retention (Figs. 7 and 8). High – high clusters of healthcare access were initially scattered but became more numerous and concentrated in parts of the central and eastern plains by 2020 – 2022, while low – low clusters diminished. In contrast, high – high clusters of population retention, initially concentrated in eastern and southern Henan, contracted substantially, whereas low – low clusters became more prominent in northern and northwestern Henan. The expansion of healthcare-access hotspots alongside the contraction of population-retention hotspots highlights the divergent evolution of their local spatial clustering patterns.

4.3 Baseline relationship

The Hausman test rejects the random-effects specification ($\mathcal{X}^2(4) = 448.52$, $p < 0.001$; Table 7). Accordingly, the baseline analysis employs county fixed effects, with robust standard errors clustered at the county level.

Table 7. Hausman test: fixed-effects versus random-effects specifications

Variable	Fixed-effects coefficient (b)	Random-effects coefficient (B)	Difference (b − B)	S.E. of difference
Healthcare access	−0.1569821	−0.0906713	−0.0663108	0.0154191
GDP, log	0.0019343	−0.0083542	0.0102885	0.0007187
GDP per capita, log	0.0184581	0.0164328	0.0020253	0.0050847
Secondary-industry value added, log	−0.0018114	0.0070871	−0.0088985	0.0006100
Hausman $\chi^2(4)$		**448.52**		
p-value		**<0.001**		

Notes: *b and B denote coefficients from the fixed-effects and random-effects specifications, respectively. S.E. denotes standard error.*

Table 8 shows a statistically significant negative association between healthcare access and population retention (coefficient = -0.157, standard error = 0.050, $p < 0.01$). The estimate

indicates that, within counties over time, higher healthcare access is associated with lower population retention, after accounting for the natural logarithms of GDP, GDP per capita and secondary-industry value added. None of these economic controls is statistically significant. The model includes 2,041 county-year observations and has a within R^2 of 0.037.

Table 8. Baseline fixed-effects estimates of the relationship between healthcare access and population retention

Variable	Baseline model
Healthcare access	−0.157***(0.050)
GDP, log	0.002(0.004)
GDP per capita, log	0.018(0.014)
Secondary-industry value added, log	−0.002(0.003)
Constant	0.113(0.132)
County fixed effects	Yes
County-clustered robust standard errors	Yes
Observations	2,041
Within R^2	0.037
F-statistic	7.57***

Notes: *The dependent variable is the population retention index. County-clustered robust standard errors are reported in parentheses. "Log" denotes the natural logarithm. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.*

The baseline results are consistent with H1, indicating a negative average association between healthcare access and population retention. Building on this finding, the following section examines care-substitution capacity as a potential mediating pathway.

4.4 Care-substitution pathway

Table 9 reports the mediation analysis results for the proposed care-substitution pathway. Healthcare access is positively associated with care-substitution capacity (coefficient = 0.4870, $p < 0.001$), whereas care-substitution capacity is negatively associated with population retention after accounting for healthcare access (coefficient = -0.1294, $p <$

0.001). The opposite signs of these coefficients indicate a negative indirect association through care-substitution capacity.

The estimated indirect association is −0.0630 ($p < 0.001$), with the Sobel test also indicating statistical significance ($z = -5.145$). The direct and total associations are −0.0556 ($p = 0.020$) and −0.1186 ($p < 0.001$), respectively. Within this mediation specification, the indirect component accounts for 53.1% of the total association.

Table 9. Mediation analysis of care-substitution capacity

Path / effect	Coefficient	S.E.	t/z	p-value	95% confidence interval
(a) Healthcare access → Care-substitution capacity	0.4870***	0.0183	26.61	<0.001	[0.451, 0.523]
(b) Care-substitution capacity → Population retention	−0.1294***	0.0257	−5.04	<0.001	[−0.180, −0.079]
Indirect effect (a × b)	−0.0630***	0.0123	−5.12	<0.001	[−0.087, −0.039]
Direct effect (c′)	−0.0556**	0.0239	−2.33	0.020	[−0.102, −0.009]
Total effect (c)	−0.1186***	0.0205	−5.79	<0.001	[−0.159, −0.078]
Indirect effect / total effect			53.1%		
Sobel test			−5.145***		
Observations			2,041		
County-level units			157		
Period			2010–2022		
County fixed effects			Yes		

Notes: *The mediator is the care-substitution capacity index. The indirect effect is calculated as a × b. S.E. denotes standard error. *** p < 0.01, ** p < 0.05, * p < 0.10.*

Together, the mediation results are consistent with H2 and extend the baseline analysis by documenting a negative indirect association through care-substitution capacity.

4.5 Infrastructure connectivity

Table 10 reports the county fixed-effects estimates of the moderating role of infrastructure connectivity, with both healthcare access and infrastructure connectivity mean-centred. The coefficient on healthcare access is negative and statistically significant (−0.207, $p < 0.01$), while the interaction coefficient is positive and significant (0.055, $p < 0.01$). The main effect

of infrastructure connectivity is not statistically significant. The positive interaction indicates that higher infrastructure connectivity is associated with a weaker negative relationship between healthcare access and population retention.

Table 10. Fixed-effects estimates of the moderating role of infrastructure connectivity

Variable	Interaction model
Healthcare access, centred	−0.207***(0.050)
Infrastructure connectivity, centred	−0.001(0.006)
Healthcare access × Infrastructure connectivity	0.055***(0.012)
GDP, log	0.003(0.004)
GDP per capita, log	0.034*(0.018)
Secondary-industry value added, log	−0.002(0.003)
Constant	−0.095(0.192)
County fixed effects	Yes
County-clustered robust standard errors	Yes
Observations	2,041
Within R^2	0.057
F-statistic	8.99***

Notes: *The dependent variable is the population retention index. Healthcare access and infrastructure connectivity are mean-centred before constructing the interaction term. County-clustered robust standard errors are reported in parentheses. "Log" denotes the natural logarithm. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.*

The marginal estimates in Table 11 further illustrate how the relationship between healthcare access and population retention varies with infrastructure connectivity. At mean-centred infrastructure connectivity levels of -1.5, 0 and 1.5, the estimated marginal associations are -0.290, -0.207 and -0.125, respectively. The associations remain negative and statistically significant across the reported range, while their absolute magnitude decreases by approximately 56.9% from the lowest to the highest connectivity level.

Table 11. Marginal association between healthcare access and population retention at different levels of infrastructure connectivity

Centred infrastructure connectivity (IFI_c)	Marginal association of healthcare access
−1.5	−0.290***(0.059)

−1.0	−0.262***(0.055)
−0.5	−0.235***(0.052)
0.0	−0.207***(0.050)
0.5	−0.180***(0.048)
1.0	−0.153***(0.047)
1.5	−0.125**(0.047)

Notes: *Marginal associations are calculated from the interaction model reported in Table 10 using mean-centred infrastructure connectivity. Standard errors are reported in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.*

These findings support H3, indicating that higher infrastructure connectivity attenuates the negative association between healthcare access and population retention.

4.6 Spatial dependence and spillovers

The LM-lag and LM-error tests indicate significant spatial dependence. Likelihood-ratio tests favour the spatial Durbin model (SDM) over the spatial-lag and spatial-error alternatives, while the Hausman test supports a fixed-effects specification.

Tables 12 – 15 report the spatial Durbin model (SDM) estimates using four spatial weight matrices: four-nearest-neighbour, six-nearest-neighbour, inverse-squared geographical distance with a 200-km threshold, and economic distance based on differences in GDP per capita. The spatial autoregressive coefficients are positive and statistically significant across all four specifications, ranging from 0.6142 under the four-nearest-neighbour matrix to 0.9156 under the economic-distance matrix. These findings indicate consistent positive spatial dependence in county-level population retention across alternative definitions of inter-county proximity.

Table 12. Spatial Durbin model estimates using the four-nearest-neighbour weight matrix

Panel A. Average effects

Variable	Direct effect	Indirect effect	Total effect
Healthcare access	−0.0194***(0.0055)	−0.0152(0.0108)	−0.0345**(0.0119)
Infrastructure connectivity	−0.0011(0.0044)	−0.0077(0.0153)	−0.0089(0.0172)
Healthcare access × Infrastructure connectivity	0.0358*(0.0148)	0.0909**(0.0309)	0.1267***(0.0349)
GDP per capita, log	−0.0184(0.0142)	0.0639***(0.0183)	0.0454*(0.0209)
GDP, log	0.0016(0.0026)	0.0015(0.0109)	0.0031(0.0127)
Secondary-industry value added, log	−0.0018(0.0022)	−0.0041(0.0102)	−0.0060(0.0118)

Panel B. Model statistics

Statistic	Estimate
Spatial autoregressive coefficient, ρ	0.6142***(0.0199)
Error variance, σ^2	0.0011***(0.0001)
Overall R^2	0.000
Observations	2,041

Notes: *The spatial weights matrix is based on the four nearest neighbours k=4. Panel A reports average direct, indirect and total effects from the spatial Durbin model. Panel B reports model-level statistics. Standard errors are reported in parentheses. "Log" denotes the natural logarithm. *** p < 0.01, ** p < 0.05, * p < 0.10.*

Table 13. Spatial Durbin model estimates using the six-nearest-neighbour weight matrix

Panel A. Average effects

Variable	Direct effect	Indirect effect	Total effect
Healthcare access	−0.0186***(0.0055)	−0.0215(0.0140)	−0.0401**(0.0152)
Infrastructure connectivity	−0.0008(0.0044)	−0.0103(0.0192)	−0.0110(0.0212)
Healthcare access × Infrastructure connectivity	0.0334*(0.0148)	0.0812*(0.0371)	0.1147**(0.0413)
GDP per capita, log	−0.0218(0.0147)	0.0713**(0.0224)	0.0494*(0.0236)
GDP, log	0.0020(0.0026)	0.0084(0.0141)	0.0104(0.0161)
Secondary-industry value added, log	−0.0019(0.0022)	−0.0089(0.0128)	−0.0108(0.0145)

Panel B. Model statistics

Statistic	Estimate
Spatial autoregressive coefficient, ρ	0.6606***(0.0193)
Error variance, σ^2	0.0011***(0.0001)
Overall R^2	0.000
Observations	2,041

Notes: *The spatial weights matrix is based on the six nearest neighbours k=6. Panel A*

*reports average direct, indirect and total effects from the spatial Durbin model. Panel B reports model-level statistics. Standard errors are reported in parentheses. "Log" denotes the natural logarithm. *** p < 0.01, ** p < 0.05, * p < 0.10.*

Table 14. Spatial Durbin model estimates using the inverse-squared geographical-distance weight matrix

Panel A. Average effects

Variable	Direct effect	Indirect effect	Total effect
Healthcare access	−0.0188***(0.0055)	−0.0516**(0.0199)	−0.0705***(0.0205)
Infrastructure connectivity	−0.0004(0.0044)	0.0110(0.0202)	0.0106(0.0224)
Healthcare access × Infrastructure connectivity	0.0344*(0.0147)	0.1258*(0.0554)	0.1601**(0.0594)
GDP per capita, log	−0.0171(0.0157)	0.0824**(0.0276)	0.0653*(0.0278)
GDP, log	0.0003(0.0026)	−0.0028(0.0188)	−0.0025(0.0208)
Secondary-industry value added, log	−0.0006(0.0022)	−0.0035(0.0164)	−0.0041(0.0180)

Panel B. Model statistics

Statistic	Estimate
Spatial autoregressive coefficient, ρ	0.7345***(0.0159)
Error variance, σ^2	0.0011***(0.0001)
Overall R^2	0.035
Observations	2,041

Notes: *The spatial weights matrix is based on inverse-squared geographical distance with a 200-km threshold. Panel A reports average direct, indirect and total effects from the spatial Durbin model. Panel B reports model-level statistics. Standard errors are reported in parentheses. "Log" denotes the natural logarithm. *** p < 0.01, ** p < 0.05, * p < 0.10.*

Table 15. Spatial Durbin model estimates using the economic-distance weight matrix

Panel A. Average effects

Variable	Direct effect	Indirect effect	Total effect
Healthcare access	−0.0148*(0.0059)	−0.1021(0.0551)	−0.1169*(0.0570)
Infrastructure connectivity	−0.0016(0.0043)	−0.1394(0.1089)	−0.1410(0.1109)
Healthcare access × Infrastructure connectivity	0.0226(0.0140)	0.1552(0.1682)	0.1778(0.1742)
GDP per capita, log	−0.0316(0.0174)	0.3414***(0.1034)	0.3099**(0.1008)
GDP, log	0.0002(0.0029)	0.0205(0.0823)	0.0207(0.0847)
Secondary-industry value added, log	−0.0010(0.0025)	−0.0713(0.0758)	−0.0723(0.0780)

Panel B. Model statistics

Statistic	Estimate

Spatial autoregressive coefficient, ρ	0.9156***(0.0112)
Error variance, σ^2	0.0008***(0.0001)
Overall R^2	0.091
Observations	2,041

Notes: *The economic-distance matrix is constructed using the inverse of differences in GDP per capita. Panel A reports average direct, indirect and total effects from the spatial Durbin model. Panel B reports model-level statistics. Standard errors are reported in parentheses. "Log" denotes the natural logarithm. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.*

The average direct effects of healthcare access on population retention are negative across all four spatial weight matrices, with estimates of -0.0194, -0.0186, -0.0188 and -0.0148, respectively. The first three estimates are statistically significant at the 1% level, while the economic-distance estimate is also reported as significant. The corresponding total effects are likewise negative, ranging from -0.0345 under the four-nearest-neighbour matrix to -0.1169 under the economic-distance matrix. The interaction between healthcare access and infrastructure connectivity also exhibits positive estimated direct and indirect effects across all four specifications, with statistically significant estimates under the three geographical weighting schemes but not under the economic-distance matrix.

The estimated average indirect effects of healthcare access are negative across all four spatial weight matrices, at -0.0152, -0.0215, -0.0516 and -0.1021 under the four-nearest-neighbour, six-nearest-neighbour, 200-km geographical-distance and economic-distance specifications, respectively. Only the 200-km geographical-distance estimate is statistically significant, while the other three estimates are not. These findings provide partial support for H4, indicating that the evidence for negative cross-county spatial spillovers varies with the definition of spatial proximity.

4.7 Temporal and regional heterogeneity

4.7.1 Temporal heterogeneity

Temporal heterogeneity is examined using the spatial model with healthcare access lagged by one year (Table 16). The analysis covers 157 county-level units over 2011–2022, comprising 1,884 county-year observations. The sample is divided into an earlier period (2011–2014) and a later period (2015–2022), containing 628 and 1,256 observations, respectively.

Table 16. Temporal heterogeneity in the lagged spatial specification

Variable / statistic	2011–2014	2015–2022
Direct effect of healthcare access	−0.0344*(0.0155)	−0.0069(0.0087)
Direct effect of healthcare access × infrastructure connectivity	0.0015(0.0574)	0.0321(0.0323)
Spatial autoregressive coefficient, ρ	0.5406***(0.0558)	0.7117***(0.0191)
Observations	628	1,256
Overall R^2	0.0165	0.0609

Notes: *Healthcare access is lagged by one year, giving an estimation period of 2011–2022. ρ denotes the spatial autoregressive coefficient. Standard errors are reported in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.*

Table 16 shows that the estimated direct effect of healthcare access is negative and statistically significant in the earlier period (−0.0344), whereas the corresponding estimate for the later period is smaller in magnitude and not statistically significant (−0.0069). The estimated direct effects of the interaction between healthcare access and infrastructure connectivity are positive in both periods (0.0015 and 0.0321, respectively), but neither is statistically significant. The spatial autoregressive coefficients are positive and significant in both periods, increasing from 0.5406 to 0.7117. Overall, the negative direct association between healthcare access and population retention is more pronounced in the earlier period,

while positive spatial dependence is observed in both periods.

4.7.2 Regional heterogeneity

For the regional heterogeneity analysis, 35 municipal districts are excluded from the full sample of 157 county-level units, leaving 122 counties and county-level cities with 1,586 county-year observations. Table 17 reports the regional estimates alongside the full-sample estimate as a benchmark for comparison.

Table 17. Regional heterogeneity in the relationship between healthcare access and population retention

Variable / statistic	Full sample	Eastern Henan	Western Henan	Southern Henan	Northern Henan	Central Henan
Healthcare access	−0.157***	−0.175	−0.110	−0.342*	0.123	0.151**
	(0.050)	(0.120)	(0.113)	(0.102)	(0.127)	(0.068)
GDP, log	0.002	0.000	0.003	−0.001	0.004	0.007
	(0.004)	(0.010)	(0.016)	(0.007)	(0.010)	(0.012)
GDP per capita, log	0.018	−0.015	−0.006	0.067	−0.025	−0.068*
	(0.014)	(0.052)	(0.031)	(0.037)	(0.038)	(0.019)
Secondary-industry value added, log	−0.002	−0.009	0.004	0.001	0.001	−0.010
	(0.003)	(0.007)	(0.013)	(0.008)	(0.008)	(0.009)
Constant	0.113	0.777	0.206	−0.285	0.440	0.949*
	(0.132)	(0.517)	(0.307)	(0.379)	(0.385)	(0.161)
Observations	2,041	260	182	364	351	429
County-level units	157	20	14	28	27	33
Within R^2	0.037	0.147	0.062	0.161	0.017	0.070
County fixed effects	Yes	Yes	Yes	Yes	Yes	Yes

Notes: *The dependent variable is the population retention index. The full-sample column includes all 157 county-level units. The regional estimates are based on 122 county-based units; 35 municipal districts included in the full panel are excluded so that the regional comparison focuses on county-based economies. County-clustered robust standard errors are reported in parentheses. "Log" denotes the natural logarithm. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.*

The association between healthcare access and population retention varies in both direction and magnitude across Henan's five regions (Table 17). Southern Henan exhibits the strongest negative association (coefficient = − 0.342), which is statistically significant. The coefficients for eastern and western Henan are also negative (− 0.175 and − 0.110, respectively), but neither is statistically significant. In contrast, northern Henan shows a positive but statistically insignificant coefficient (0.123), whereas central Henan exhibits a statistically significant positive association (0.151).

The negative association observed in the full sample (−0.157) therefore masks substantial regional variation in the relationship between healthcare access and population retention.

4.8 Robustness checks

Table 18 reports two alternative specifications assessing the robustness of the baseline relationship between healthcare access and population retention. When healthcare access is lagged by one year, its estimated coefficient remains negative and statistically significant (− 0.184, standard error = 0.055), based on 1,884 county-year observations. Adding year fixed effects to the baseline county fixed-effects model also yields a significant negative coefficient for healthcare access (−0.192, standard error = 0.056), with 2,041 observations.

Table 18. Robustness checks for the healthcare–retention relationship

Variable / statistic	(1) Baseline	(2) Lagged healthcare access	(3) County + year fixed effects
Healthcare access	−0.157*** (0.050)		−0.192*** (0.056)
Healthcare access, t−1		−0.184*** (0.055)	
GDP, log	0.002 (0.004)	0.001 (0.004)	0.000 (0.003)
GDP per capita, log	0.018 (0.014)	0.029* (0.015)	0.055 (0.044)

Secondary-industry value added, log	−0.002 (0.003)	−0.002 (0.003)	0.000 (0.002)
County fixed effects	Yes	Yes	Yes
Year fixed effects	No	No	Yes
Observations	2,041	1,884	2,041
Within R^2	0.037	0.035	0.286

Notes: *The dependent variable is the population retention index. Column (1) reports the baseline county fixed-effects model; column (2) uses healthcare access lagged by one year; and column (3) adds year fixed effects to the baseline model. County-clustered robust standard errors are reported in parentheses. "Log" denotes the natural logarithm. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.*

Compared with the baseline estimate of −0.157, both alternative specifications produce consistently negative and statistically significant coefficients. The negative association between healthcare access and population retention therefore persists when healthcare access is measured with a one-year lag and when common year-specific influences are accounted for, supporting the robustness of the baseline finding.

5 Discussion

5.1 Beyond amenities: the labour-allocation effect of public services

Existing research has emphasised the amenity and welfare functions of public services, linking improvements in service provision to living conditions, local attractiveness and residential choices (Tiebout, 1956; Xia and Lu, 2015). The negative average association between healthcare access and population retention observed in this study points to another dimension of this relationship. It suggests that public services may also influence the choices available to rural households, bringing household labour allocation into view alongside local living conditions.

We conceptualise this dimension as the labour-allocation effect of public services. The New Economics of Labour Migration views migration as part of a household strategy for allocating labour and managing risk, rather than solely as an individual decision (Stark and Bloom, 1985; Taylor, 1999). From this perspective, improved local healthcare can reduce the need for family members to remain continuously available to meet household care needs, expanding their employment and mobility options. Healthcare improvements may therefore enhance the welfare of residents who remain locally while allowing other household members greater flexibility in how and where they allocate their labour.

The regional heterogeneity results further highlight the importance of local context. The negative association observed in the full sample is not uniform across Henan, with regional estimates differing in both direction and magnitude. These patterns suggest that the demographic implications of improved healthcare depend partly on the opportunities available to households as their care-related constraints change. The labour-allocation perspective thus provides a framework for understanding variation in population-retention outcomes across regions.

5.2 Service beneficiaries and potential migrants

The labour-allocation perspective draws attention to a distinction between those who directly benefit from healthcare services and those whose employment and mobility choices may change as care arrangements evolve. In ageing rural households, older family members may be the principal beneficiaries of improved local healthcare, while working-age members often arrange medical appointments, accompany relatives to treatment and respond to other care-related needs. These responsibilities can require working-age family members to remain

locally available, constraining their employment and mobility choices. By easing some of these demands, improved healthcare access may provide households with greater flexibility in allocating labour across locations.

Research on caregiving and labour mobility shows that parental health and family care responsibilities can shape labour supply and migration decisions (Ettner, 1995; Bolin et al., 2008; Giles and Mu, 2007). Studies of formal and informal care suggest that organised services can substitute for some forms of support otherwise provided by family members (Charles and Sevak, 2005; Bonsang, 2009). Evidence from China further indicates that home-based eldercare services can reduce certain forms of instrumental support provided by adult children (Sun et al., 2023). Together, this literature informs the care-substitution pathway proposed in this study: as local healthcare and related services assume some care-related tasks, they may ease the constraints shaping working-age family members' labour-market choices.

The mediation results are consistent with the proposed care-substitution pathway. Healthcare access is positively associated with county-level care-substitution capacity, which is in turn negatively associated with population retention. The estimated indirect component accounts for 53.1% of the total association within the mediation specification. The care-substitution capacity index is based on welfare beds per capita, hospital and township-health-centre beds per capita, and road-network density; the healthcare-bed component also contributes to the healthcare access index. Together, these findings provide evidence of a negative indirect association through care-substitution capacity, supporting the interpretation that improvements in local services may reshape household care constraints and the

labour-allocation choices available to family members.

5.3 Local employment absorption and conditional demographic effects

The demographic implications of greater flexibility in household labour allocation may depend partly on the availability and geographical distribution of employment opportunities. The regional heterogeneity results illustrate this variation. Among the 122 counties and county-level cities included in the analysis, southern Henan exhibits the strongest negative association between healthcare access and population retention, whereas central Henan shows a positive and statistically significant association. These contrasting estimates suggest that regional employment conditions may shape how changes in household care constraints relate to population retention.

Local employment absorption offers a useful perspective on these regional differences. Research on rural migration and economic regeneration highlights how employment prospects influence decisions to remain, return or seek work elsewhere (Stockdale, 2006; Zhang and Mu, 2026). Where suitable local jobs are limited, greater flexibility in household labour allocation may make employment outside the county more attractive. Where local and nearby labour markets offer viable opportunities, working-age family members may instead pursue non-farm employment locally or take up jobs in nearby areas while maintaining their residence.

The moderation results further illustrate the conditional role of infrastructure connectivity. The positive interaction between healthcare access and infrastructure connectivity indicates that higher connectivity attenuates the negative association between healthcare access and

population retention. Across the reported range, the estimated marginal association changes from -0.290 to -0.125. Infrastructure connectivity may facilitate access to employment beyond the county while also strengthening links to local and nearby labour markets. This pattern is consistent with the proposed balance between mobility-cost reduction and local-employment absorption, with the latter offering a plausible explanation for the observed attenuation. Together with the regional heterogeneity results, these findings highlight the importance of local economic conditions and wider labour-market connections in shaping the demographic implications of healthcare improvement.

5.4 Spatial embeddedness of public-service effects

The spatial results extend the analysis of healthcare access and population retention from individual counties to their wider regional relationships. Population retention exhibits positive spatial dependence under all four spatial weight matrices, while the estimated average indirect effects of healthcare access are negative in each specification. Of these indirect effects, only the estimate under the inverse-squared geographical-distance matrix with a 200-km threshold is statistically significant. These findings provide partial support for H4 and indicate that evidence of negative cross-county spatial spillovers is sensitive to how inter-county proximity is defined.

Rural households are embedded in regional labour markets shaped by economic centres, employment opportunities and infrastructure connections that extend beyond individual county boundaries. The availability of jobs across these markets may influence how working-age family members balance employment choices with household care responsibilities. As households organise their employment and care arrangements across

locations, improvements in healthcare access in one county may be associated with population-retention outcomes elsewhere. These inter-county connections provide a broader spatial context for understanding the relationship between public-service provision and rural demographic change.

These spatial relationships draw attention to a distinction between the administrative boundaries of public-service provision and the geographical scope of household labour allocation. Healthcare services are largely organised and delivered within territorial jurisdictions, whereas employment and care arrangements may span several counties. Assessing the demographic implications of service provision therefore requires attention to regional labour-market connections and population interdependence alongside outcomes within individual administrative units.

5.5 Apparent coordination and the limits of coupling metrics

Between 2010 and 2022, the coupling coordination degree between healthcare access and population retention increased, with its classification shifting from “moderate disorder” to “barely coordinated”. Over the same period, healthcare access improved substantially, whereas population retention declined overall. We describe this coexistence of a rising coordination measure and contrasting trajectories in the two underlying indices as apparent coordination.

The analytical significance of apparent coordination lies in how coupling coordination metrics are interpreted. The coupling coordination degree combines the degree of coupling between healthcare access and population retention with their composite development level,

while the individual indices reveal the direction and magnitude of change in each system. Considering these measures together helps distinguish an increase in the composite coordination score from simultaneous improvements in the underlying systems. This distinction highlights the value of examining both composite measures and their constituent indicators when assessing the relationship between public-service provision and rural demographic change.

The spatial and regression findings provide further context for the pattern of apparent coordination. High–high clusters of healthcare access expanded while those of population retention contracted, and the regression results indicate a negative average association between the two indices, with variation across regions. These findings complement the temporal and coupling coordination results by revealing how public-service improvement and population retention are related across different spatial contexts. Considered alongside the evidence on care substitution and infrastructure connectivity, they highlight the value of the labour-allocation perspective for interpreting rural demographic change in relation to household care constraints, employment opportunities and regional labour-market connections.

6 Conclusions, policy implications and limitations

6.1 Conclusions

Using a balanced panel of 157 county-level units in Henan Province, China, from 2010 to 2022, this study examines the relationship between healthcare access and population retention from a household labour-allocation perspective. By combining composite indices, county

fixed-effects estimation, mediation and moderation analyses, and spatial econometric models, the study investigates the temporal, spatial and conditional dimensions of this relationship.

The findings reveal contrasting trends in healthcare access and population retention. Healthcare access improved substantially over the study period, whereas population retention declined overall. Although the coupling coordination degree increased, the divergent trajectories of the underlying indices reveal a pattern of apparent coordination. The baseline results show a statistically significant negative average association between healthcare access and population retention. This association remains negative and statistically significant when healthcare access is lagged by one year and when year fixed effects are included.

The mediation results provide evidence consistent with the proposed care-substitution pathway. Healthcare access is positively associated with county-level care-substitution capacity, which is in turn negatively associated with population retention. This pattern suggests that improvements in local healthcare and related services may ease household care constraints and expand the employment and mobility choices available to family members, linking public-service provision to household labour allocation.

The relationship between healthcare access and population retention also varies across local and regional contexts. Higher infrastructure connectivity attenuates the negative association, while regional estimates reveal contrasting patterns, including a significant negative association in southern Henan and a significant positive association in central Henan. In the temporally split lagged spatial model, the estimated direct effect is negative and statistically significant in 2011–2014 but smaller and statistically insignificant in 2015–2022. Spatial models further reveal positive spatial dependence in population retention across all four

weight matrices, while the negative indirect effect of healthcare access is statistically significant only under the 200-km geographical-distance specification, providing partial support for H4.

Taken together, these findings position household labour allocation as a further dimension of the relationship between rural public services and demographic change. They highlight the value of considering healthcare provision alongside household care constraints, local employment opportunities and regional labour-market connections when interpreting differences in population retention across places.

6.2 Policy implications

These findings suggest that rural healthcare planning and local economic development would benefit from closer coordination. Improving healthcare access remains central to residents' wellbeing, while opportunities in local and nearby labour markets may shape how households respond as care-related constraints change. In counties with limited non-farm employment, healthcare improvements could be accompanied by measures to strengthen locally viable industries, expand service-sector opportunities and improve connections to nearby employment centres. In areas with stronger employment bases, coordinated improvements in healthcare and local employment opportunities may help sustain both quality of life and population retention. Such an approach would broaden the options available to rural households in deciding where to live and work.

Healthcare and eldercare services offer another opportunity to link improvements in residents' wellbeing with local employment development. Better integration of primary healthcare,

community-based eldercare and home-based support could improve access to everyday care while easing some of the responsibilities borne by family caregivers. As population ageing increases demand for these services, their expansion may also support employment in healthcare, eldercare and related local service activities. Attention to service accessibility, care quality and workforce development could help meet the needs of older residents while enabling working-age family members to participate more flexibly in employment.

Public-service planning and evaluation would also benefit from greater attention to regional connections. The spatial dependence observed in population retention highlights the relevance of relationships among neighbouring and economically connected counties. Regional coordination could help align healthcare provision, infrastructure connectivity and labour-market development across administrative boundaries. Evaluation frameworks could consider trends in healthcare access and population retention, together with demographic structure and local employment conditions, alongside coupling coordination scores. Such a combined assessment would provide a fuller picture of how public-service improvements relate to demographic change across interconnected rural regions.

6.3 Limitations and future research

The county-level fixed-effects and supplementary models establish a consistent association between healthcare access and population retention, while changes in unobserved local conditions and reciprocal relationships between service provision and demographic change remain relevant to its interpretation. Future research could draw on phased healthcare reforms, policy pilots or other quasi-experimental variation to identify the effects of healthcare improvements on rural population outcomes more precisely.

The care-substitution pathway also calls for more direct measurement of household arrangements. The care-substitution capacity index captures county-level service resources and infrastructure rather than changes in caregiving arrangements within households, and it shares healthcare-resource information with the healthcare access index. Household panel data on caregiving time, formal healthcare and eldercare use, and family members' employment choices would allow a more direct examination of how local services reshape care responsibilities and labour allocation. Measures of care provision that are more distinct from healthcare access would further clarify this pathway.

A further priority is to observe population mobility and inter-county connections more directly. The population retention index combines county-level measures of population, employment and socioeconomic activity, while the spatial models represent inter-county proximity using alternative weighting schemes. Origin–destination migration records, commuting flows and information on where family members work and use healthcare services would provide a more detailed account of how labour mobility and care arrangements relate to demographic change. Linking these data to county-level measures could help distinguish different forms of mobility and examine the geographical reach of public-service effects.

Finally, the findings reflect the demographic and economic conditions of Henan Province, a major agricultural and labour-exporting region of China. The relationship between healthcare access, household care arrangements and population retention may differ across areas with other employment structures, migration patterns, population profiles and healthcare systems. Comparative research across Chinese provinces and other rural settings would help clarify the

circumstances in which public-service improvements are associated with different patterns of household labour allocation and population retention.

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Figure legends

Figure 1. Conceptual framework.

Note: Solid arrows represent hypothesised relationships, whereas dashed lines indicate moderating, spatial or descriptive relationships. The coupling coordination degree is used only as a descriptive diagnostic.

Figure 2. Study area.

Note: The base map was obtained from the Standard Map Service of the Ministry of Natural Resources of the People's Republic of China (map approval no. GS(2024)0650). The administrative boundaries were not modified.

Figure 3. Trends in healthcare access and population retention, 2010–2022.

Note: Values represent annual means of the healthcare access and population retention indices across the 157 county-level units.

Figure 4. Coupling coordination between healthcare access and population retention, 2010 – 2022.

Note: D denotes the coupling coordination degree between the healthcare access and population retention indices.

Figure 5. Spatial distribution of healthcare access, 2010, 2015, 2020 and 2022.

Note: The maps show the spatial distribution of the healthcare access index across county-level units in Henan Province. Colours indicate relative categories of healthcare access.

Figure 6. Spatial distribution of population retention, 2010, 2015, 2020 and 2022.

Note: The maps show the spatial distribution of the population retention index across county-level units in Henan Province. Colours indicate relative categories of population retention.

Figure 7. LISA cluster maps of healthcare access, 2010, 2015, 2020 and 2022.

Note: The maps show Local Indicators of Spatial Association (LISA) clusters of healthcare access across county-level units in Henan Province. HH and LL denote High – High and Low – Low spatial clusters, respectively; HL and LH denote High – Low and Low – High spatial outliers.

Figure 8. LISA cluster maps of population retention, 2010, 2015, 2020 and 2022.

Note: The maps show Local Indicators of Spatial Association (LISA) clusters of population retention across county-level units in Henan Province. HH and LL denote High – High and

Low–Low spatial clusters, respectively; HL and LH denote High–Low and Low–High spatial outliers.

Data availability

The datasets, statistical code and supporting documentation underpinning this study, including variable definitions, data transformations and calculation procedures, are provided in the supplementary archive data.zip. These materials are accessible to editors and peer reviewers through the journal's submission system. There are no restrictions on sharing these materials.

Ethical Approval

This article does not contain any studies with human participants performed by any of the authors. Ethical approval was not required because the research used secondary, county-level aggregate statistical data and did not involve the recruitment of human participants.

Informed Consent

Informed consent was not required because the study did not involve human participants or the collection of individual-level personal data.

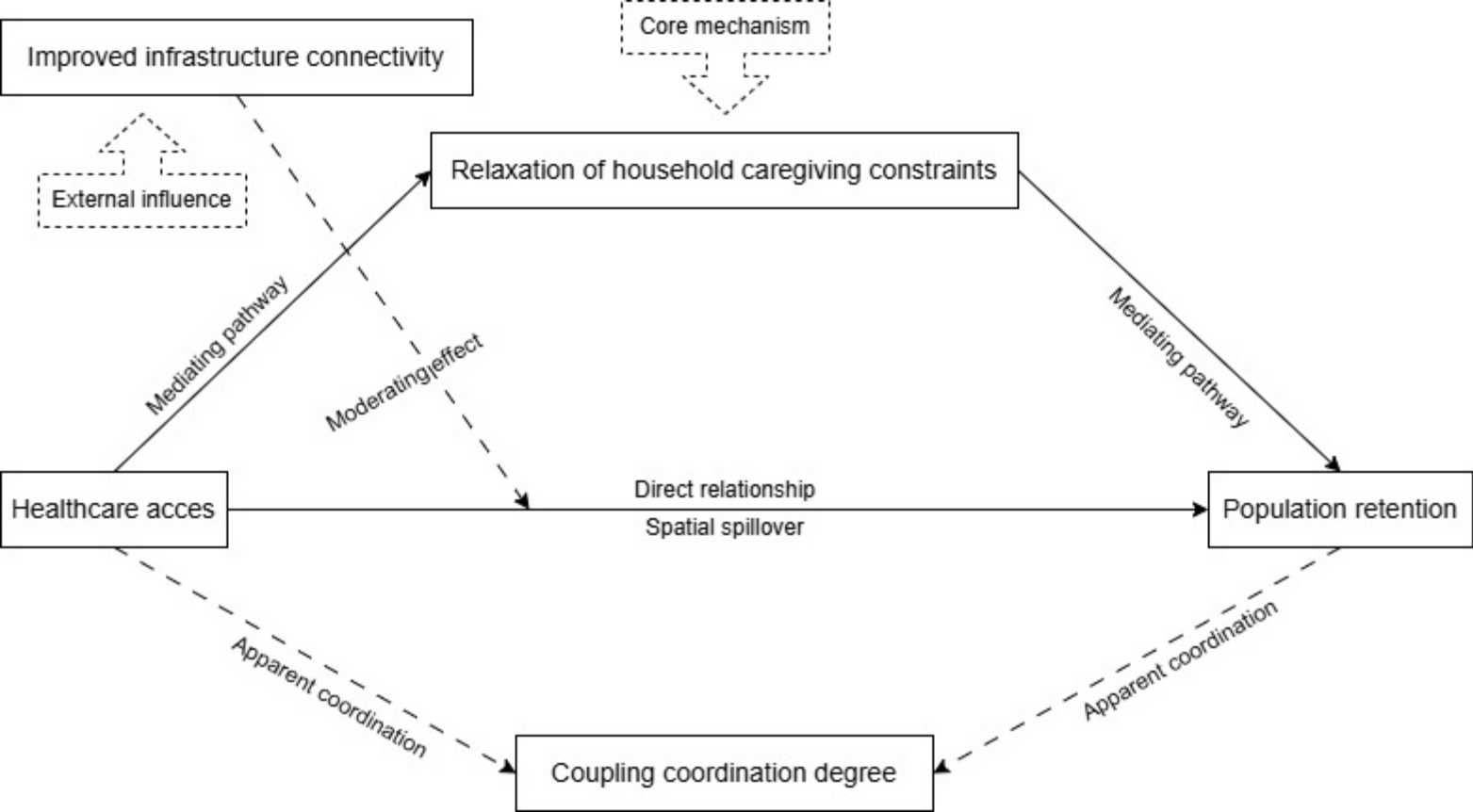
Competing interests

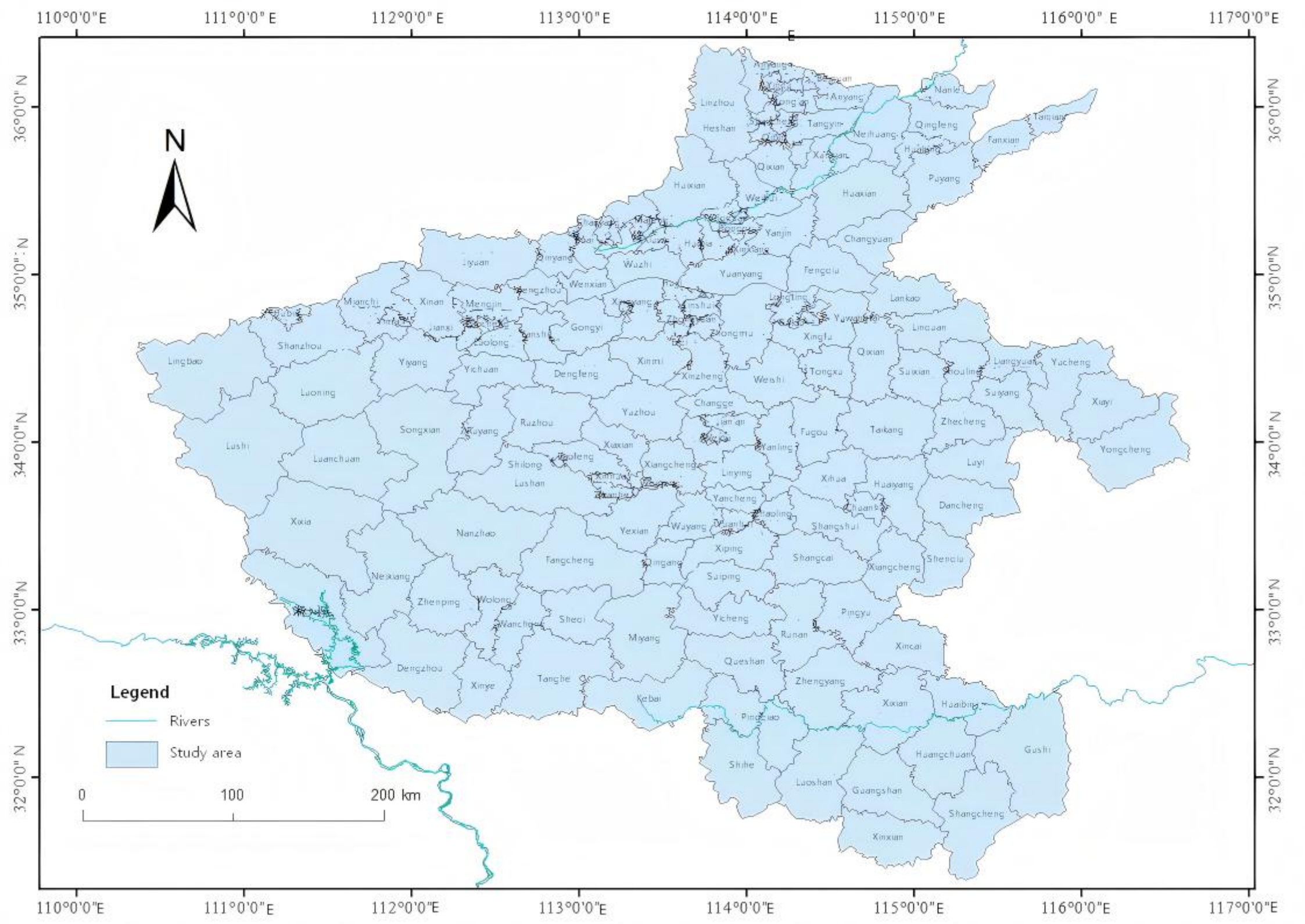
The authors declare no competing interests.

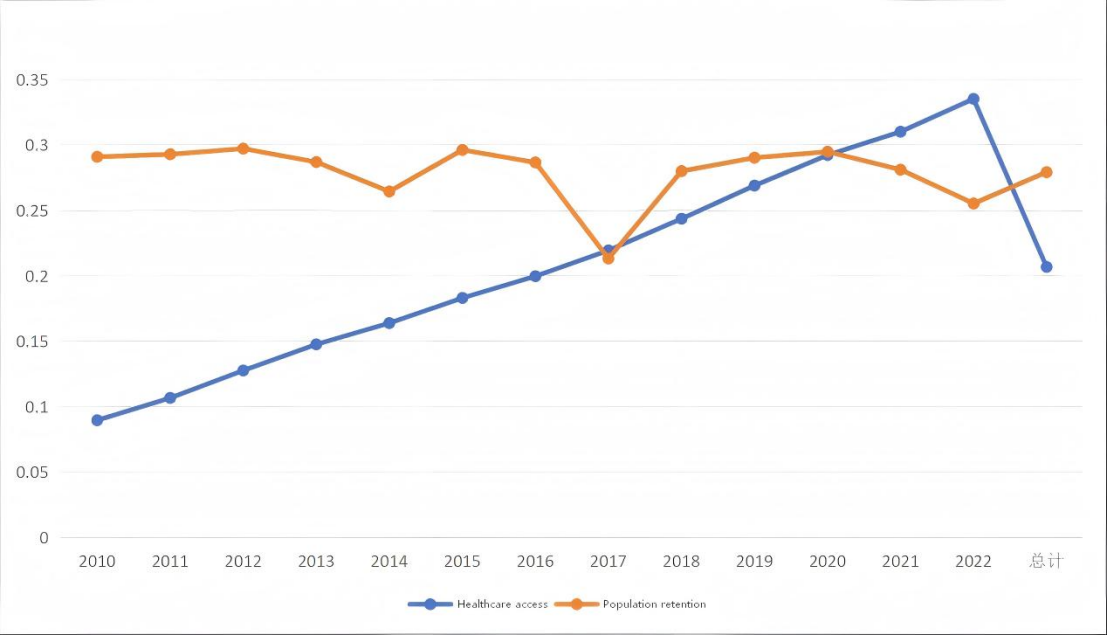
Author contributions

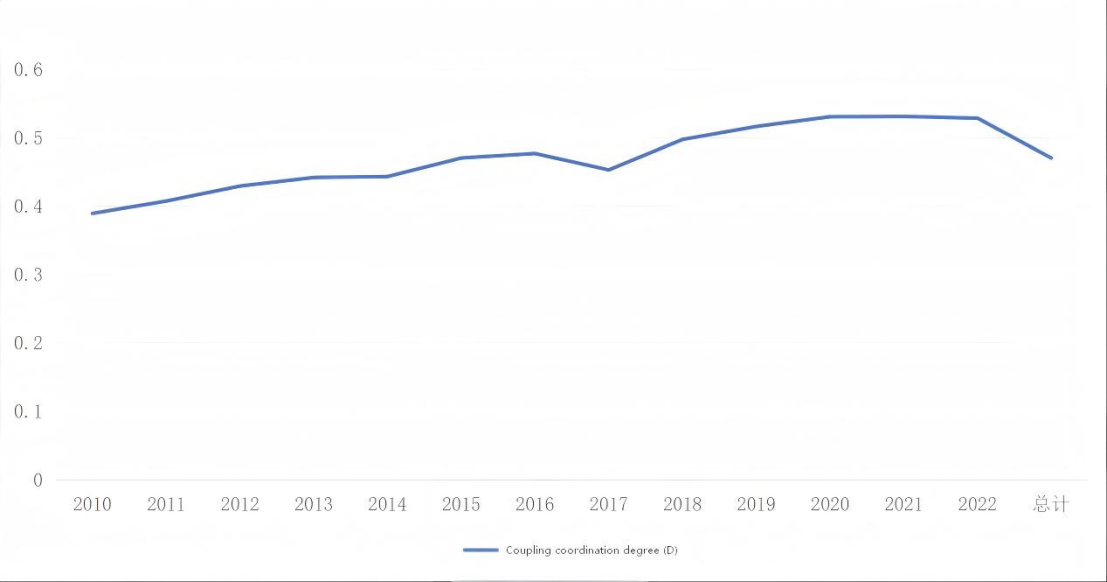
W.S. and F.W. conceived and designed the study. W.S. conducted the formal analysis and drafted the original manuscript. M.C.L. contributed to the methodology, validation and

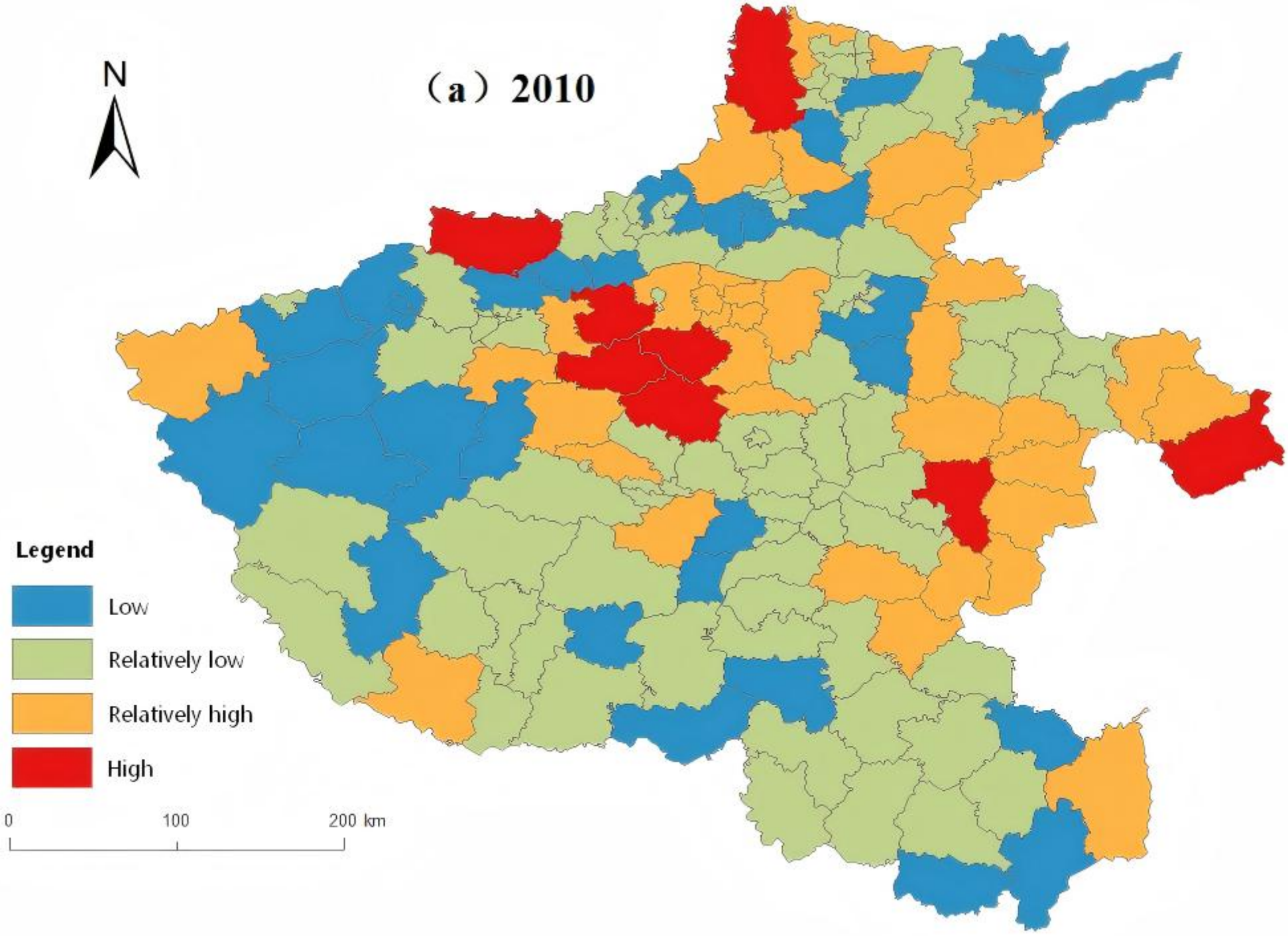
interpretation of the results. S.W. contributed to data curation, spatial analysis and visualisation. M.Y.L. contributed to data curation, literature review and manuscript revision. F.W. supervised the study, contributed to the conceptualisation and interpretation of the findings, and critically revised the manuscript. All authors reviewed and approved the final manuscript.

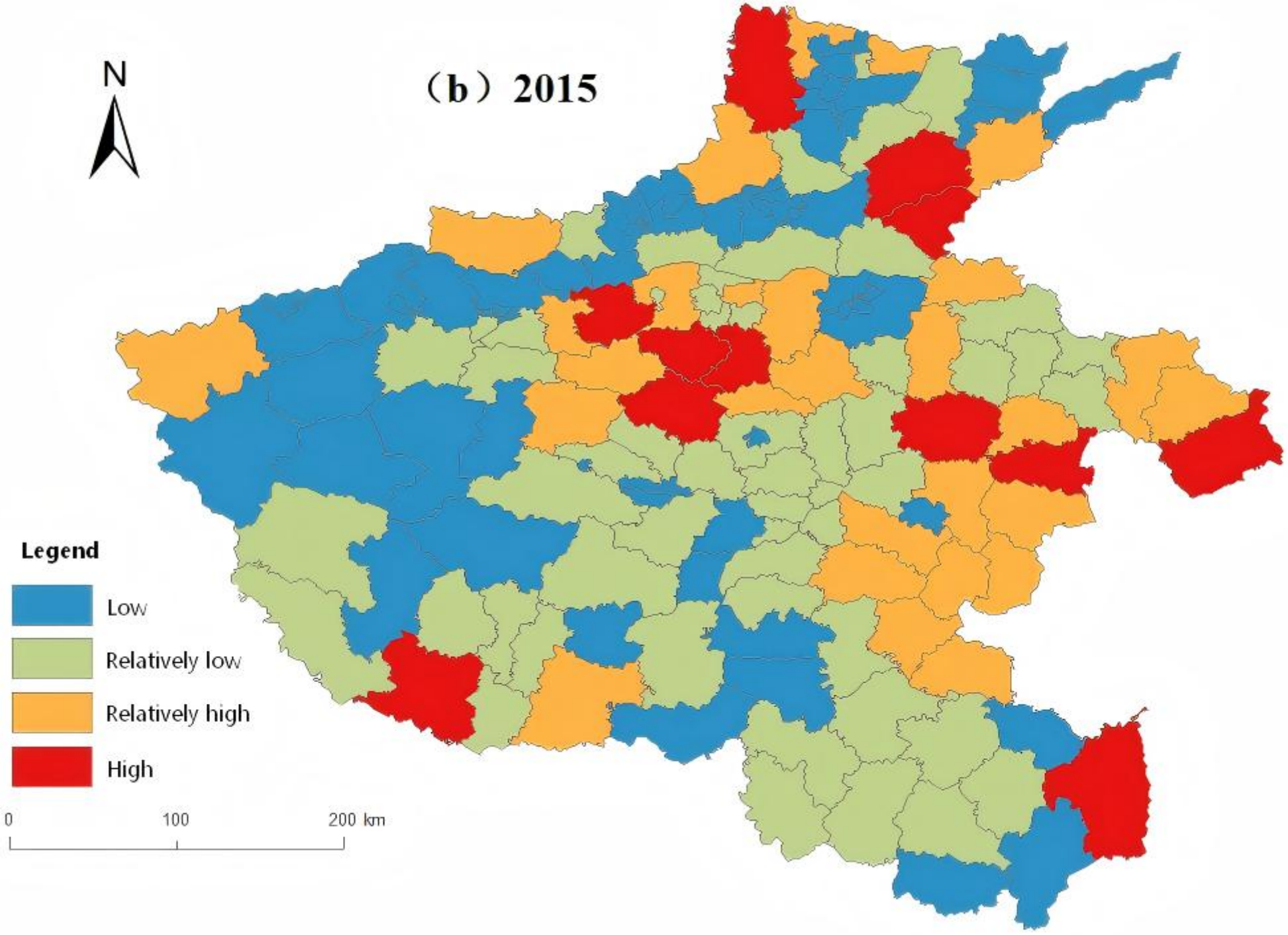

Improved infrastructure connectivity
Core mechanism
External influence
Relaxation of household caregiving constraints
Mediating pathway
Moderating effect
Mediating pathway
Healthcare acces
Direct relationship
Spatial spillover
Population retention
Apparent coordination
Apparent coordination
Coupling coordination degree

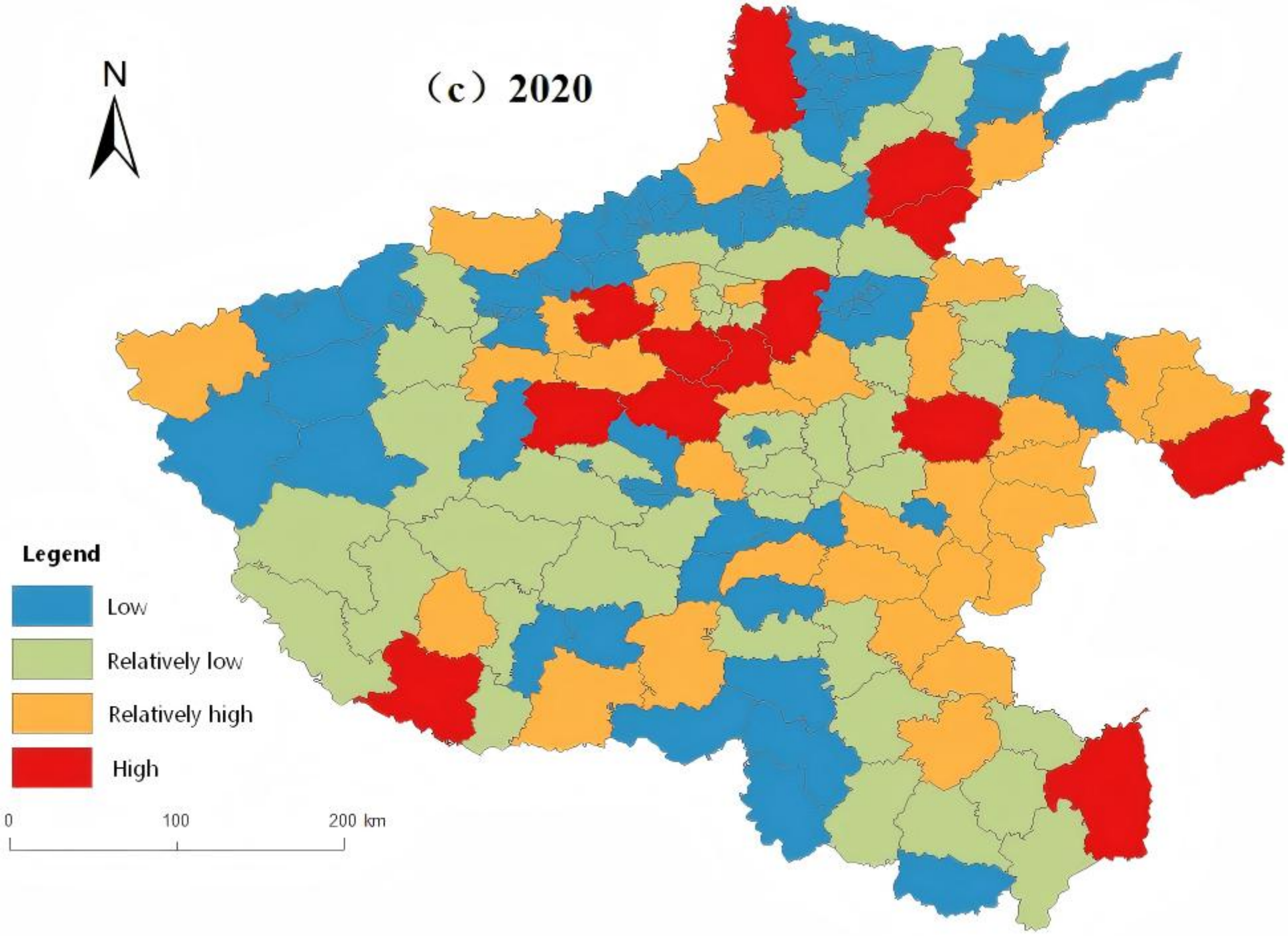

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Linzhou
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Fanxian
Puyang
Huaxian
Qixian
Yanjin
Changyuan
Yuanyang
Fengqiu
Lankao
Yuwangtai
Lingbao
Shanzhou
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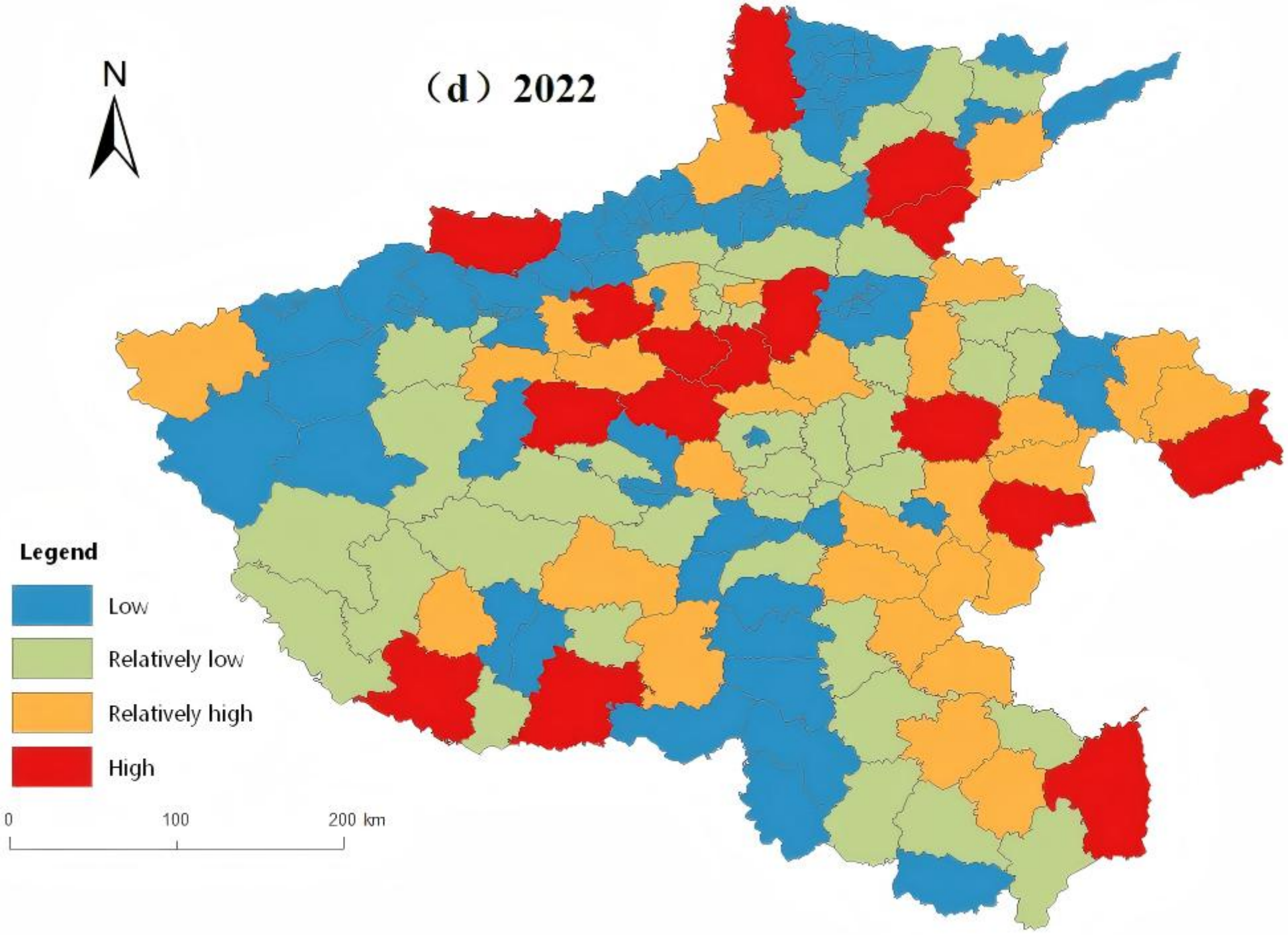

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2022
总计
Healthcare access
Population retention

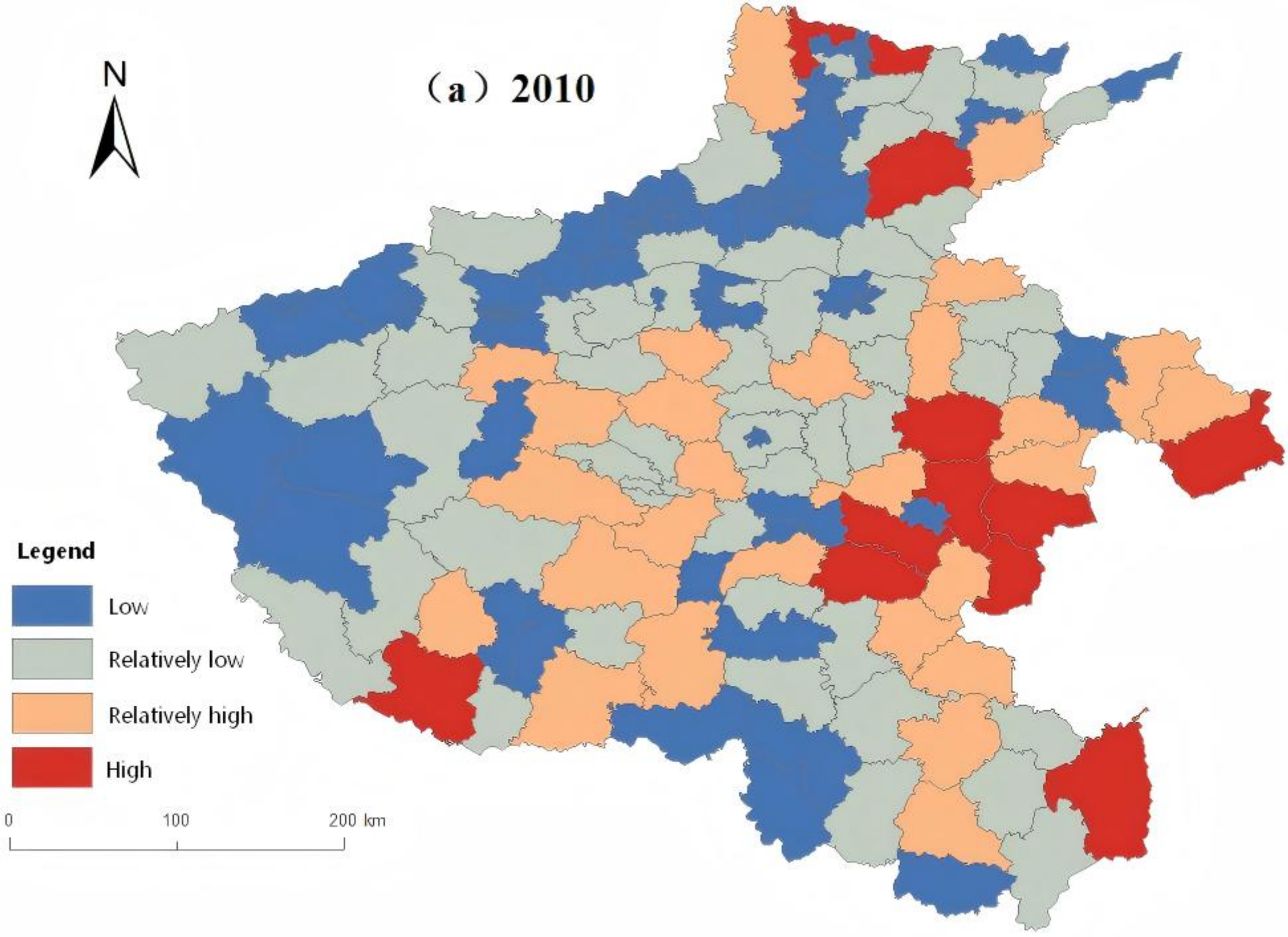

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总计
Coupling coordination degree (D)

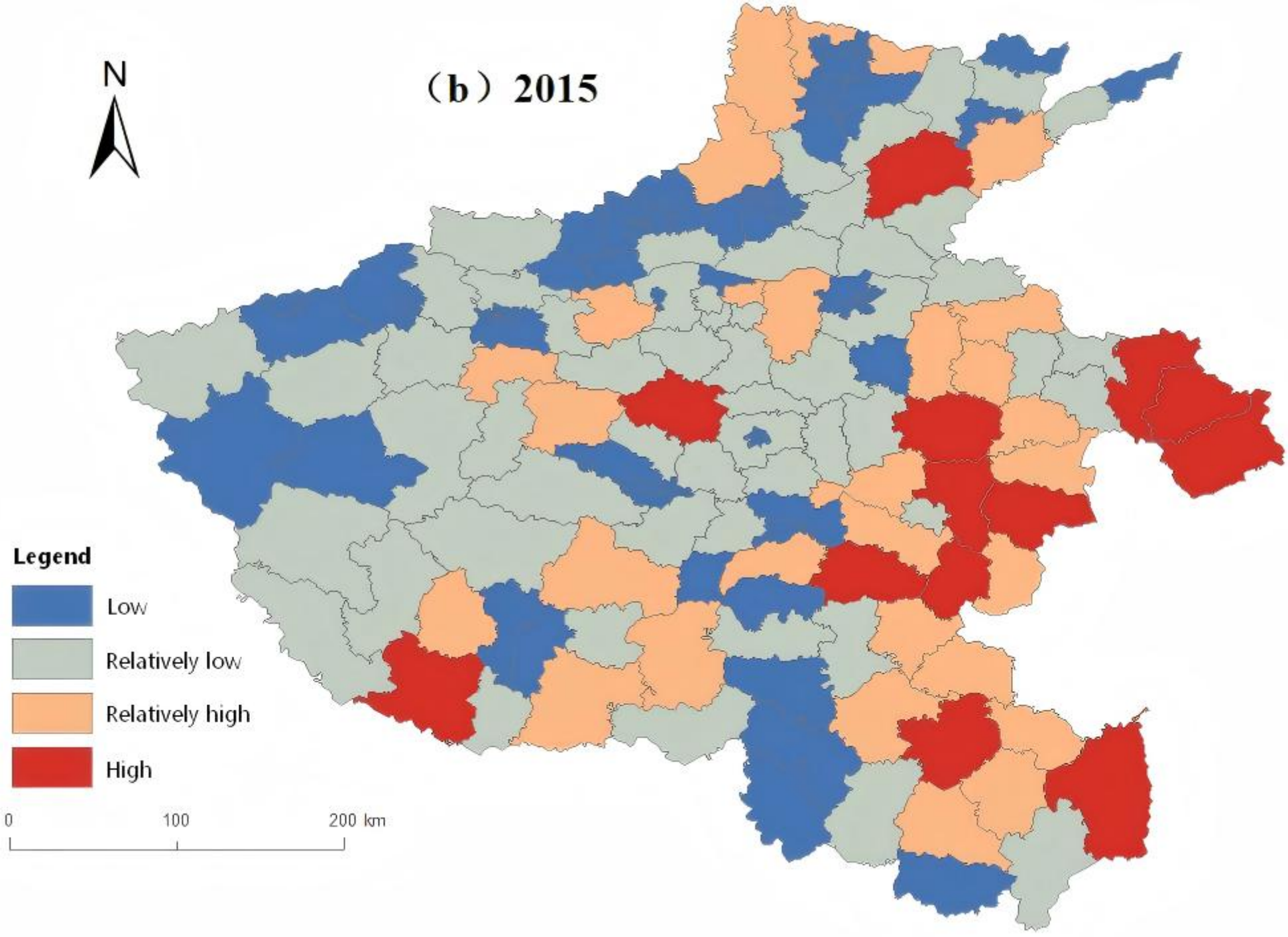

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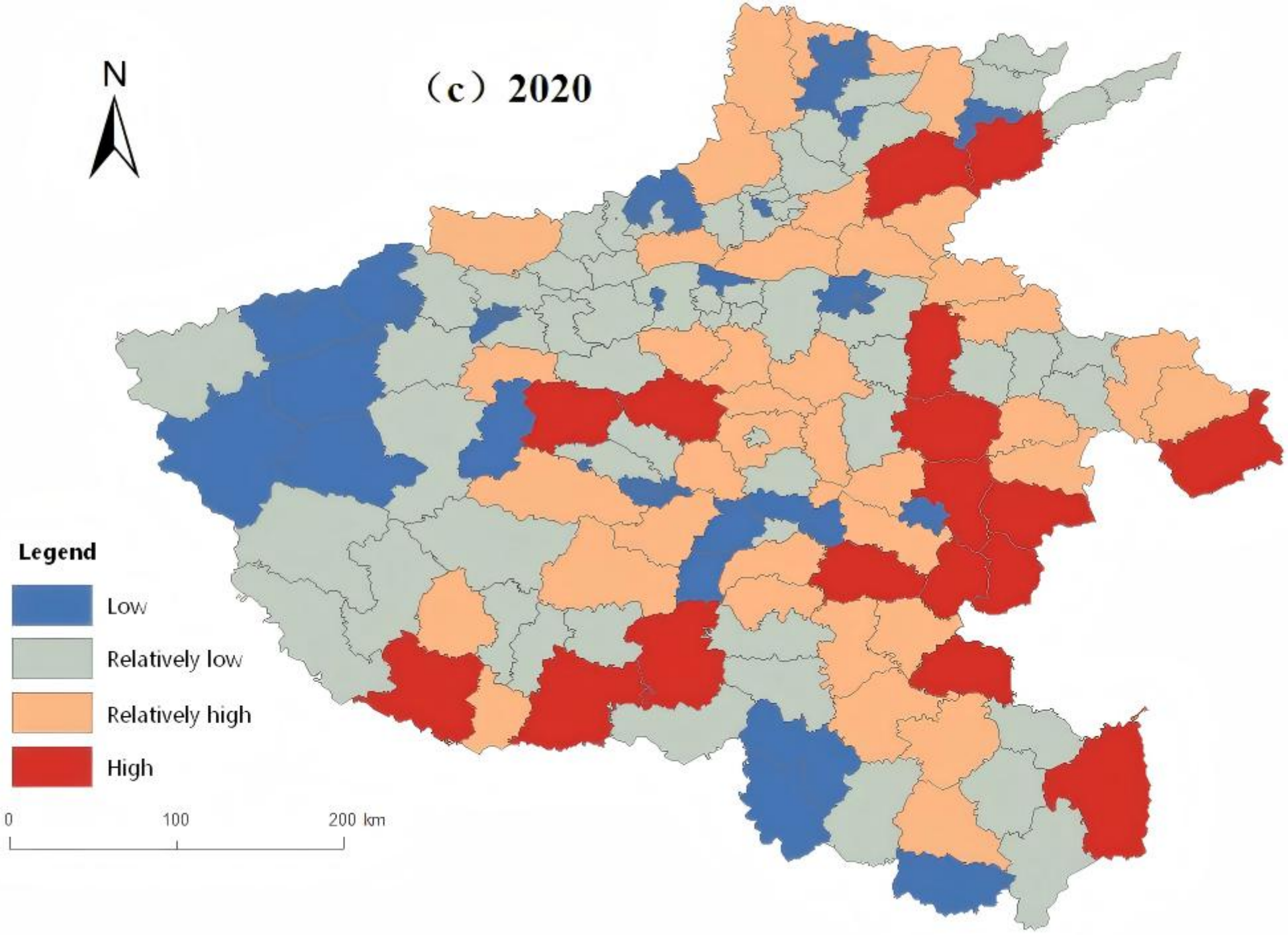

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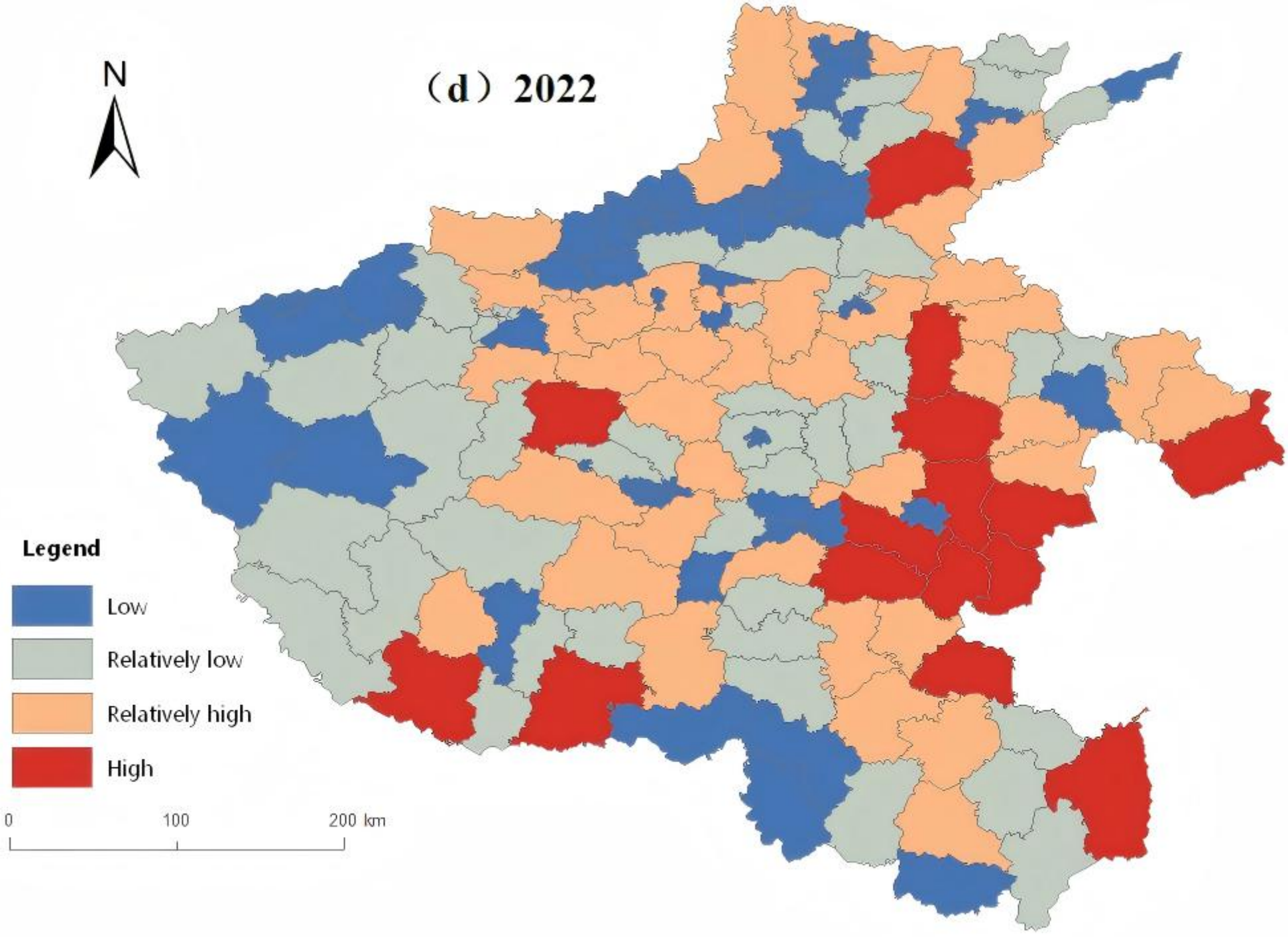

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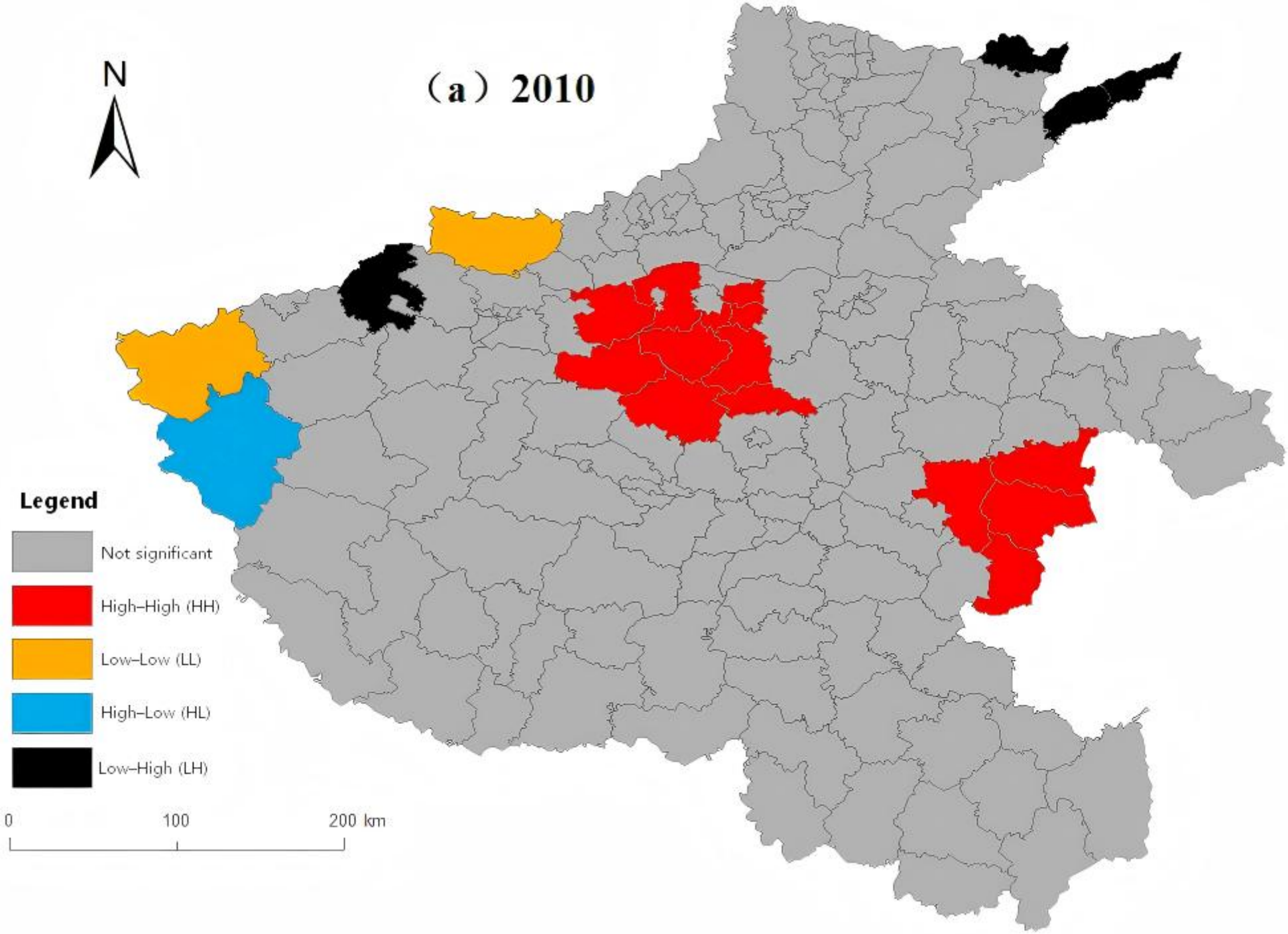

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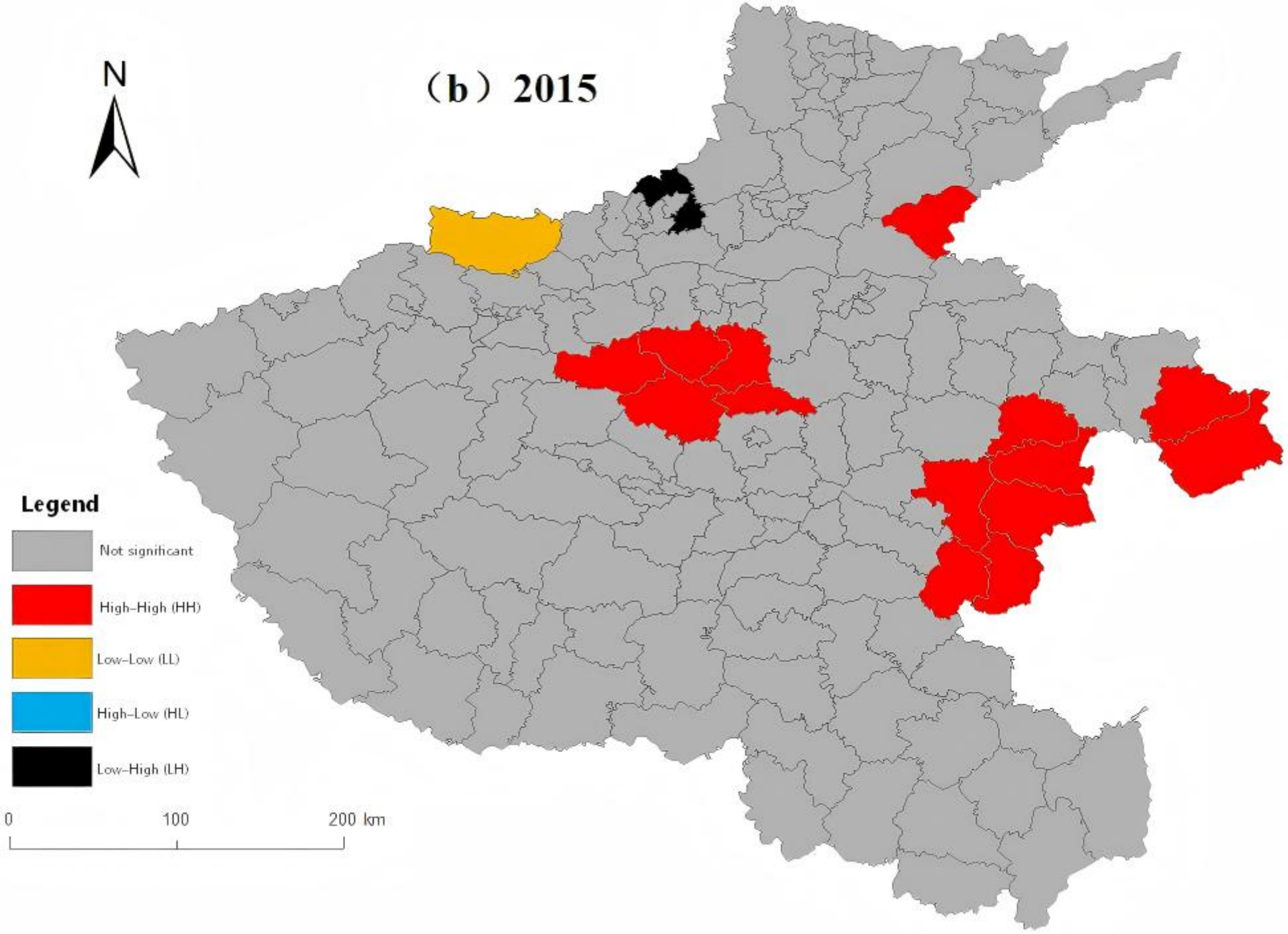

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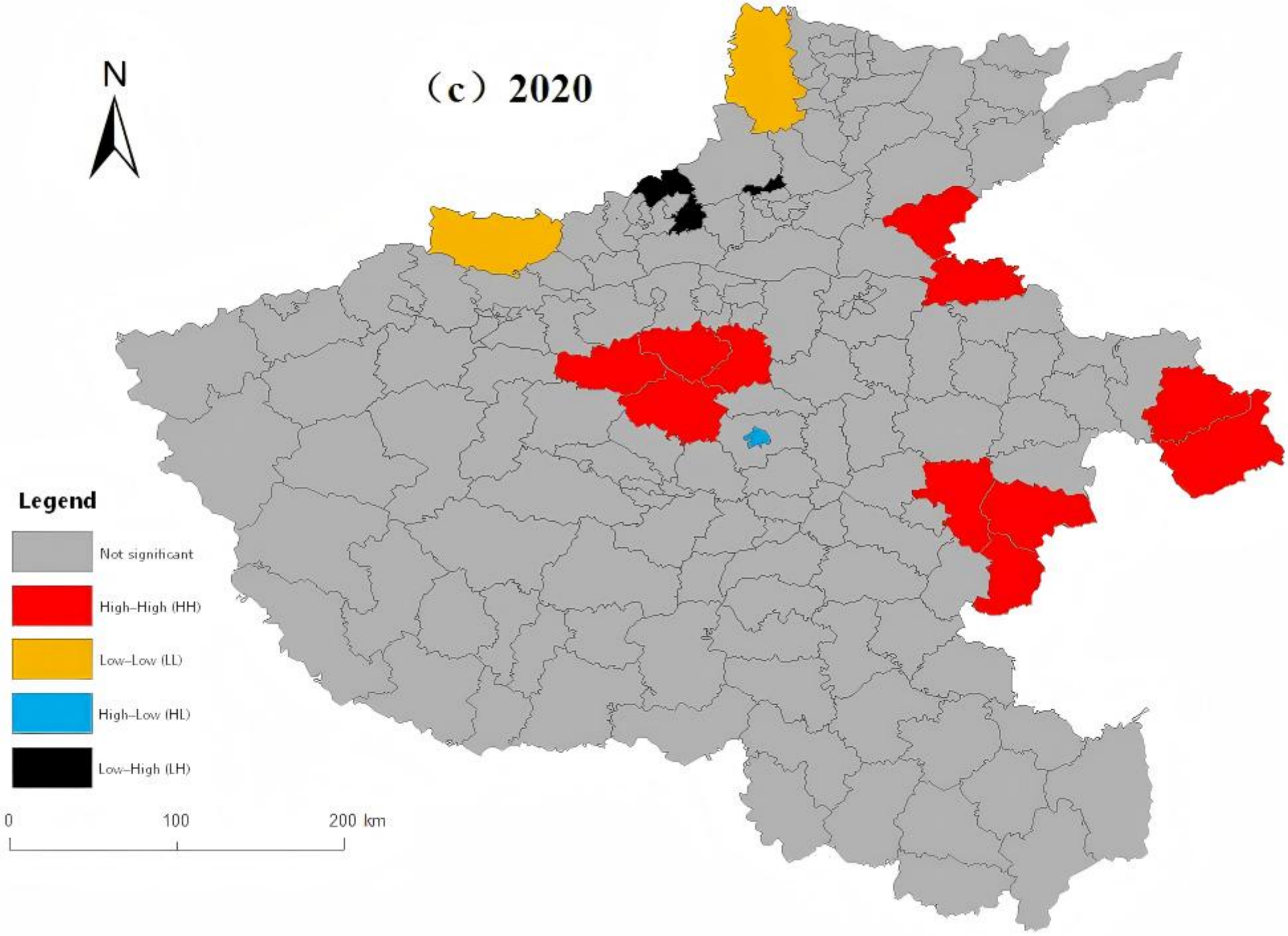

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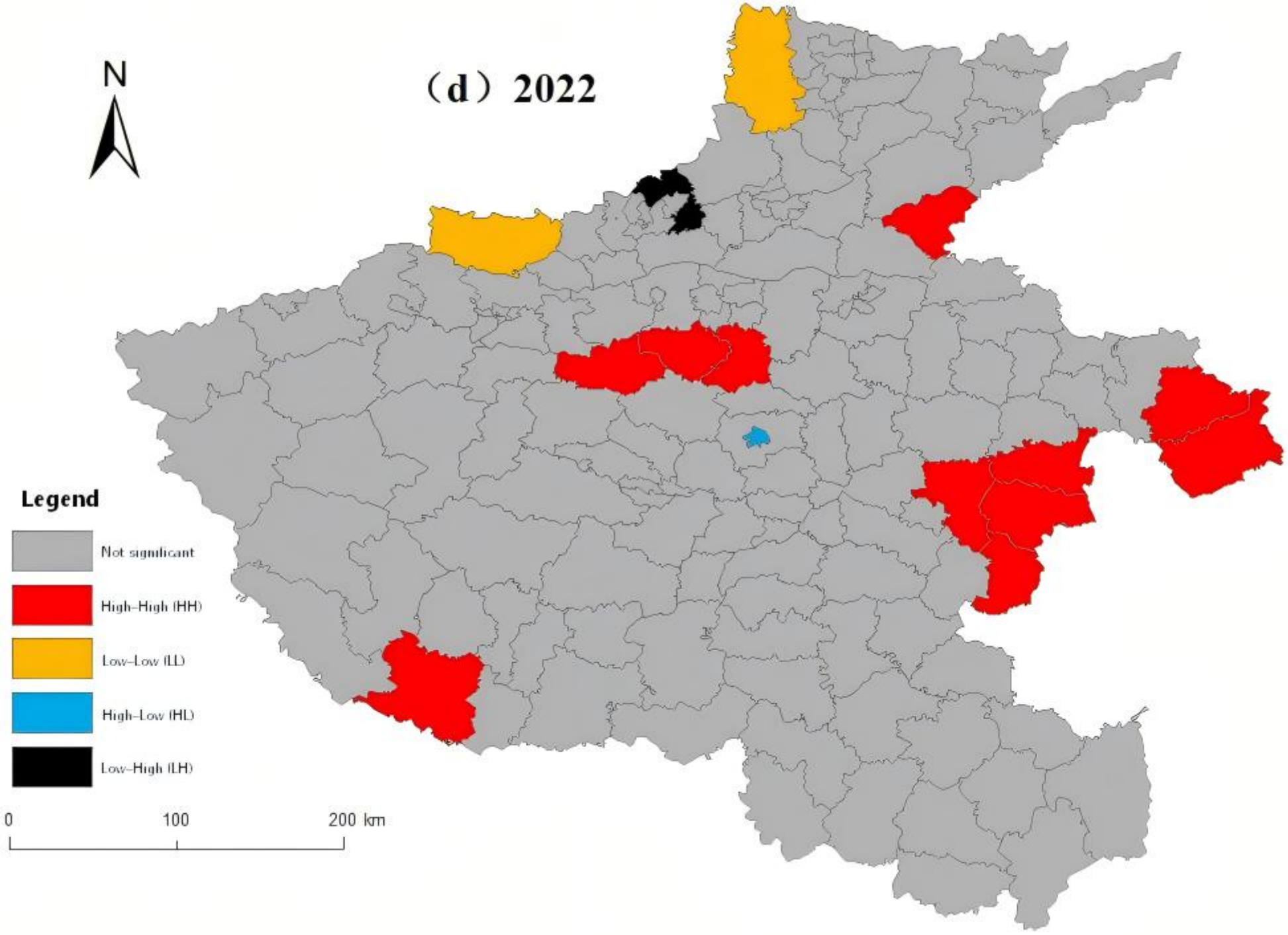

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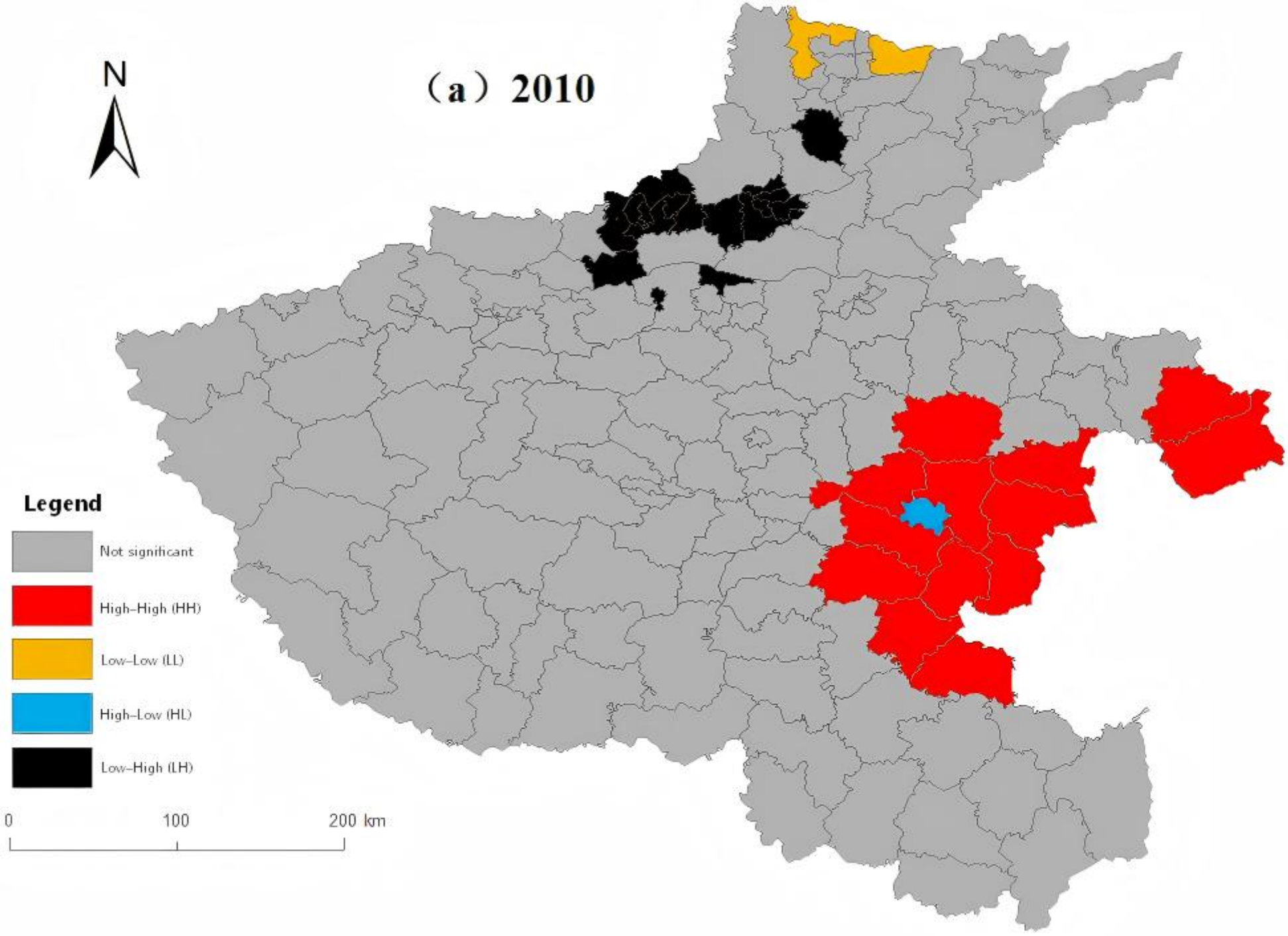

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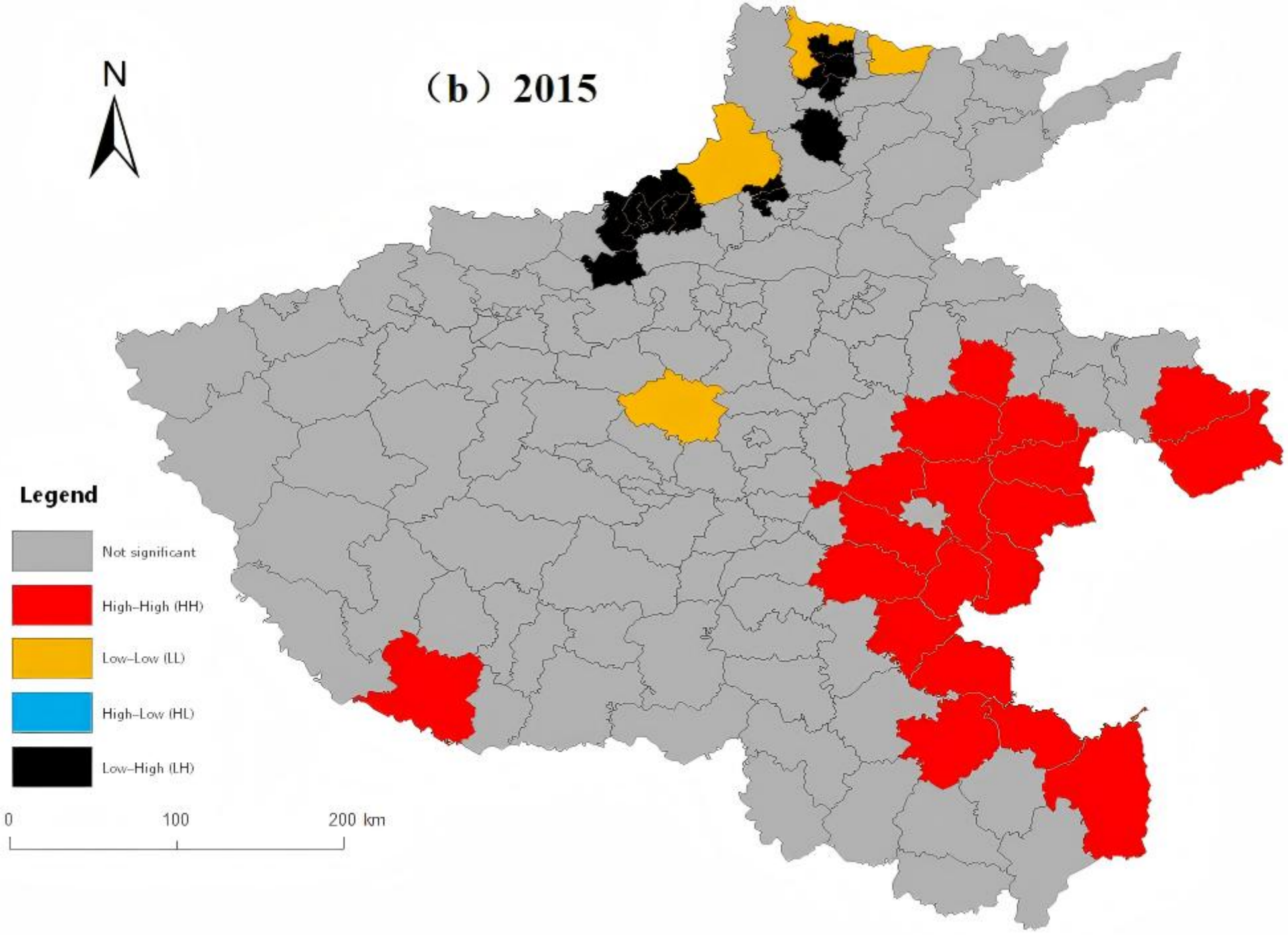

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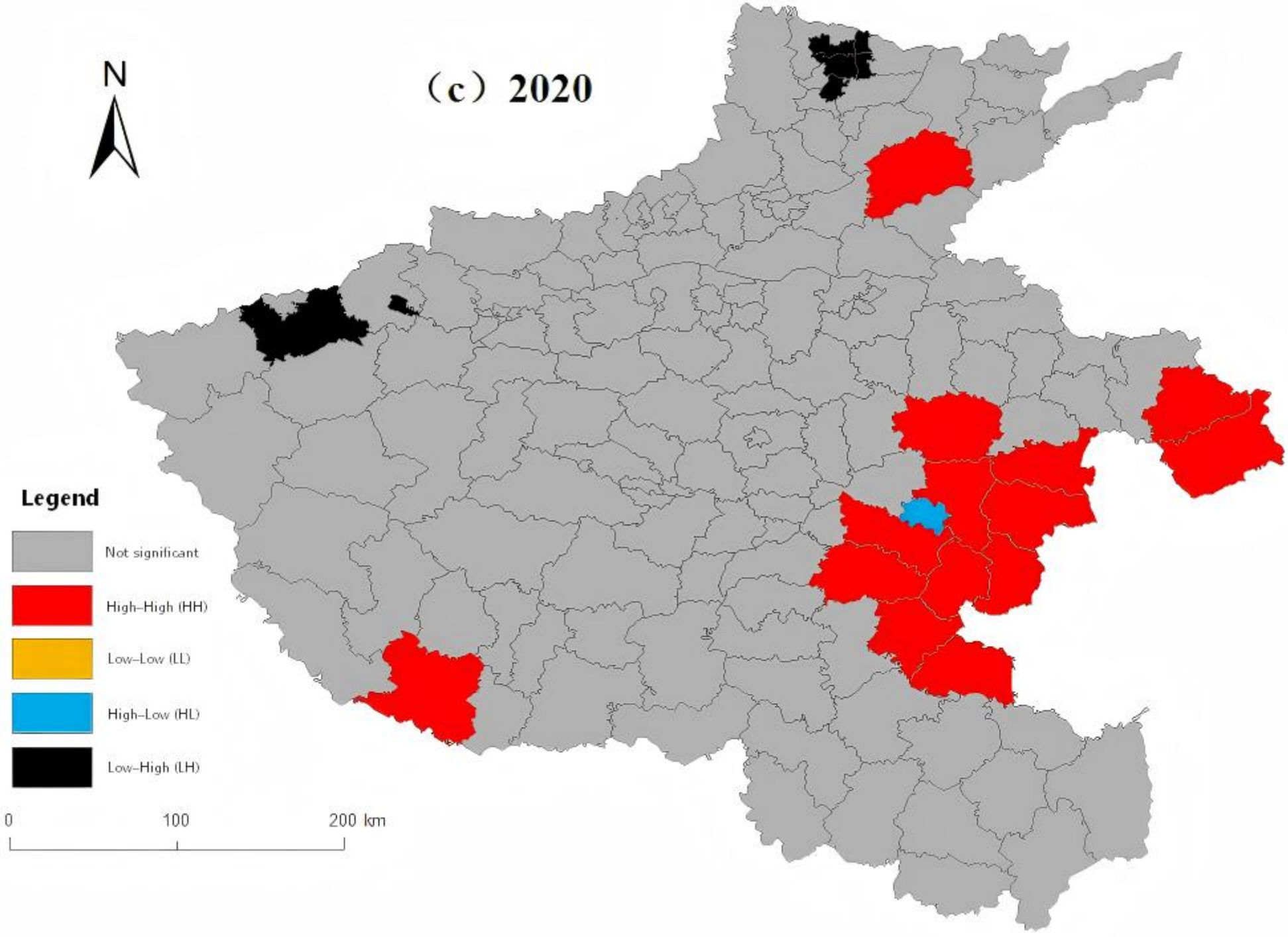

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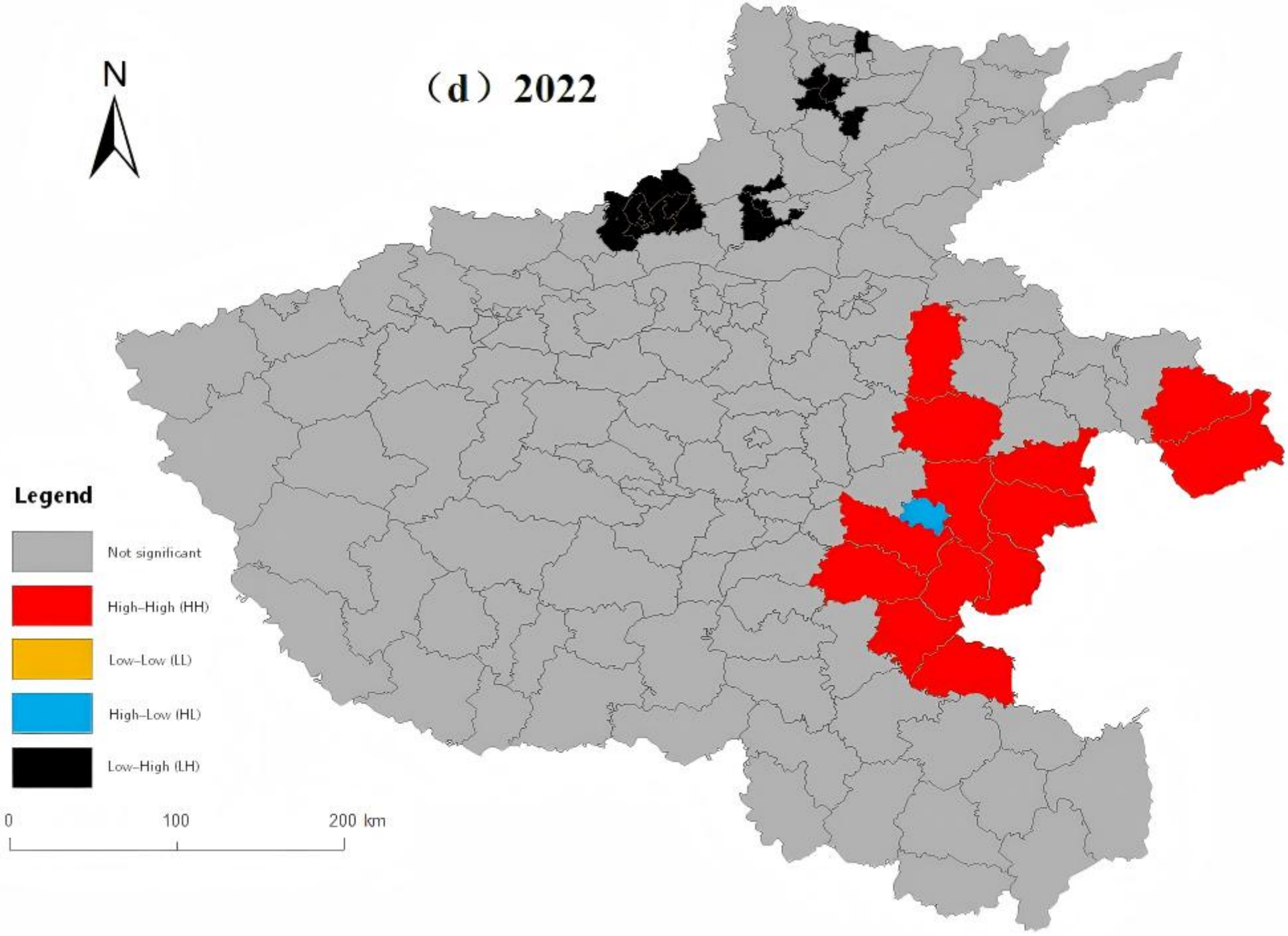

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