THE SPATIAL STRUCTURE CHARACTERISTIC AND ROAD TRAFFIC ACCESSIBILITY EVALUATION OF A-LEVEL TOURIST ATTRACTIONS WITHIN WUHAN URBAN AGGLOMERATION IN CHINA

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Reception: 21/05/2023 **Acceptance**: 22/07/2023 **Publication**: 13/08/2023

Suggested citation:

Liao, W., Wang, H., and Xu, J. (2023). **The Spatial Structure Characteristic and Road Traffic Accessibility Evaluation of A-Level Tourist Attractions within Wuhan Urban Agglomeration in China**. *3C Tecnología. Glosas de innovación aplicada a la pyme, 12(3)*, 388-409. https://doi.org/10.17993/3ctecno.2023.v12n3e45.388-409

ABSTRACT

Against the backdrop of the post-pandemic COVID-19, regional short-distance tourism has become more prevalent. This paper used Wuhan Urban Agglomeration (WUA) as the research area and explored spatial structure characteristics and road traffic accessibility issues of A-level tourist attractions within WUA. The geospatial analysis methods of Average Nearest Neighbour (ANN) and Kernel Density Estimation (KDE) were used to identify the spatial structure distribution of A-level tourist attractions. Constructing Weighted Network Analysis to measure the traffic access time between tourist attractions and traveler origin and further using Network Analysis to measure the traffic access time between different tourist attractions. The traffic access time results were spatially visualized using Inverse Distance Weight (IDW). The study results were as follows. (1) The spatial structure of A-level tourist attractions in WUA indicated a core-periphery distribution in general. All tourist attractions showed clustering characteristics of the spatial distribution pattern. The spatial clustering degree was highest for human tourist attractions and lowest for nature tourist attractions. (2) Traffic access time results exhibited significant centrality with Wuhan as the core and regional differences in WUA. The road traffic accessibility of human tourist attractions was better than that of natural tourist attractions. (3) The spatial distribution and road traffic accessibility of tourist attractions in WUA indicated a circle structure centered on Wuhan, which aligned with the general rule of regional development. The accessibility of the north-south direction was weaker than the east-west direction in WUA. (4) Human tourist attractions were mainly concentrated in urban areas with high connectivity and intensive road networks. But natural tourist attractions were separated from traveler origin and other different tourist attractions. Most were in mountainous and hilly areas with poor accessibility, which could attract more tourists with better road networks and traffic infrastructure.

KEYWORDS

Tourist Attractions; National A-Level; Spatial Structure Characteristic; Road Traffic Accessibility Evaluation; Wuhan Urban Agglomeration (WUA), China

https://doi.org/10.17993/3ctecno.2023.v12n3e45.388-409

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https://doi.org/10.17993/3ctecno.2023.v12n3e45.388-409

1. INTRODUCTION

Accompanied by the rapid development of the Chinese economy, its economic growth mode was gradually inclined to the tertiary industry, and the position of the tourism industry was increasingly important in its social development [1]. In recent years, tourism has become a pillar industry of national development, and the theoretical study of urban tourism in China started late but developed very rapidly [2]. As an essential symbol for measuring the quality of attraction spots, Chinese national A-level tourist attractions were an essential indicator of the unique rating standard and resource standardization management, which played a positive role in promoting the construction of tourist attractions and the development of the tourism economy since its promotion in 1999 [3]. As one of the basic prerequisites for tourism operations, regional transportation was a critical factor in relating tourists to tourism destinations [4]. In the increasingly fierce competition faced by global tourist attractions, the requirements of consumers for tourist attractions were becoming higher and higher, with accessibility, attraction service quality and sustainable development serving as important competitive advantages [5]. Some scholars conducted forward-looking analyses to capture the supply and demand for regional tourism based on the importance of transportation elements to tourism facilities and the potential impact on regional tourist attractions [6]. Therefore, a correct understanding of the attraction's situation was essential in achieving optimal allocation and development of tourism resources.

The spatial structure and traffic accessibility of tourist attractions as the research hotspot were explored by scholars through mathematical statistics and spatial metrology. In terms of studies related to the spatial structure of tourist attractions, some scholars constructed a system conceptual model to improve the governance for regional tourism elements based on the development of land policies, which were used to optimize the design specifications and functions of the region's tourism [7]. Some scholars quantitatively studied the spatial pattern and accessibility of auto campsites in Chinese Beijing from the perspective of self-driving tourism [8]. Some scholars summarised the influencing factors affecting the distribution by analyzing the spatial distribution characteristics of tourism towns in the Wuling Mountains region of China [9]. In addition, some scholars explored the distribution of tourist attractions, the misallocation of resources and the future development trend from the perspective of spatial allocation dynamics [10]. In terms of studies related to the traffic accessibility of tourist attractions, some scholars explored the impact on regional spatial accessibility differences by using traffic data with different attributes, such as highway networks [11]. Some scholars used a potential model with different effective service radii to measure the spatial traffic accessibility of care facilities [12]. Some scholars investigated and designed tourism products by considering the accessibility problem of shore excursions with the limited docking time of cruise ships as the background [13]. Some scholars evaluated the accessibility issues of tourist attractions and perceptions of consumer satisfaction through empirical studies from rural tourism facilities, popular tourist attractions and protected tourism islands to optimize

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management initiatives of regional tourism [14, 15, 16]. In addition, some scholars analyzed the impact of high-speed rail on regional transport accessibility and tourism economic linkages and further explored the synergistic effect of accessibility and tourism economic development through a coupled coordination degree evaluation model [17]. Based on the intrinsic correlation between tourism efficiency and location accessibility, some scholars quantitatively modeled the impact of accessibility on the total tourism output of attractions areas and its efficiency change [18].

Tourist attractions were a core tourism component and a prerequisite for its development. The spatial structure and accessibility of tourist attractions determined the behavior of tourists and profoundly influenced tourism development strategies [19]. Studies indicated that the development of short-distance tourism and the state of transportation development were important factors that affected the evolution of the spatial structure of attraction spots [20], and the short-term tourism trend of using short public holidays was becoming increasingly obvious [21]. In addition, the COVID-19 outbreak dramatically changed the behaviour of tourists [22], short-distance tourism was gradually becoming more popular in tourism after the post-pandemic. Therefore, this paper started from the research gap of a few empirical and applied studies on short-distance tourism and selected WUA (nine cities centered on Wuhan) as an appropriate scope of the study area for short-distance tourism. Through an empirical case study of the WUA region, the spatial structure of A-level tourist attractions was identified, and the road traffic accessibility of short-distance travel within the region was further measured. The study results were helpful in suggesting the development and optimization of the spatial layout of tourist attractions in WUA and providing scientific guidance for creating and managing A-level tourist attractions in the future.

2. METHODOLOGY

2.1. DESCRIPTION OF THE STUDY AREA

Wuhan Urban Agglomeration (WUA) was known as Wuhan "1+8" City Circle in the eastern part of Hubei Province within China. WUA was centered on Wuhan and covered Huanggang, Ezhou, Huangshi, Xianning, Xiantao, Qianjiang, Tianmen and Xiaogan (Figure 1). According to statistical information, its geographical location was in the Yangtze River's middle reaches and the Jianghan Plain's east-central part, with an area of about 57800 km².

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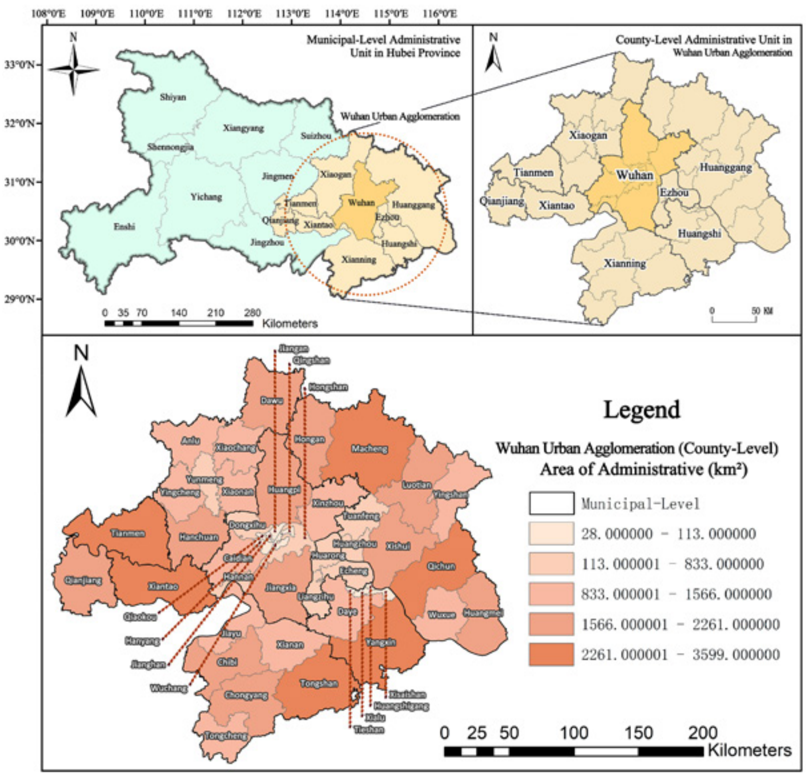

Figure 1. Location Map of Wuhan Urban Agglomeration (WUA) in China

2.2. DATA COLLECTION

This paper's data included the national A-level tourist attractions list, the total resident population and GDP. The list of national A-level tourist attractions within WUA was based on publicly available data from the Hubei Provincial Department of Culture and Tourism in China (http://wlt.hubei.gov.cn/). The national A-level attractions were evaluated and recognized by the China National Tourism Administration based on the indicators of landscape quality, historical and cultural value, service facilities provision and management level. A-level attractions were detailed into 1A, 2A, 3A, 4A and 5A, with 5A as the highest level of assessment. The total regional resident population was obtained from the 7th Chinese Population Census Bulletin of the National Bureau of Statistics (http://www.stats.gov.cn/). GDP data from Hubei Provincial Statistical Yearbook 2021 published by the Hubei Provincial Statistics Bureau in China (https://tjj.hubei.gov.cn/). This paper used the map projection coordinate system WGS_1984_UTM_Zone_49N for geographic data processing.

The county-level unit under the administrative jurisdiction of nine cities was used as the scale for this paper (48 county-level administrative units in total). As of 2021, 214 A-level tourist attraction spots existed in WUA. According to the different categories of tourist attractions, the tourist attractions were classified into two categories: natural and human. The final statistics were collected with 94 sites in the natural attractions and 120 sites in the human attractions (Figure 2).

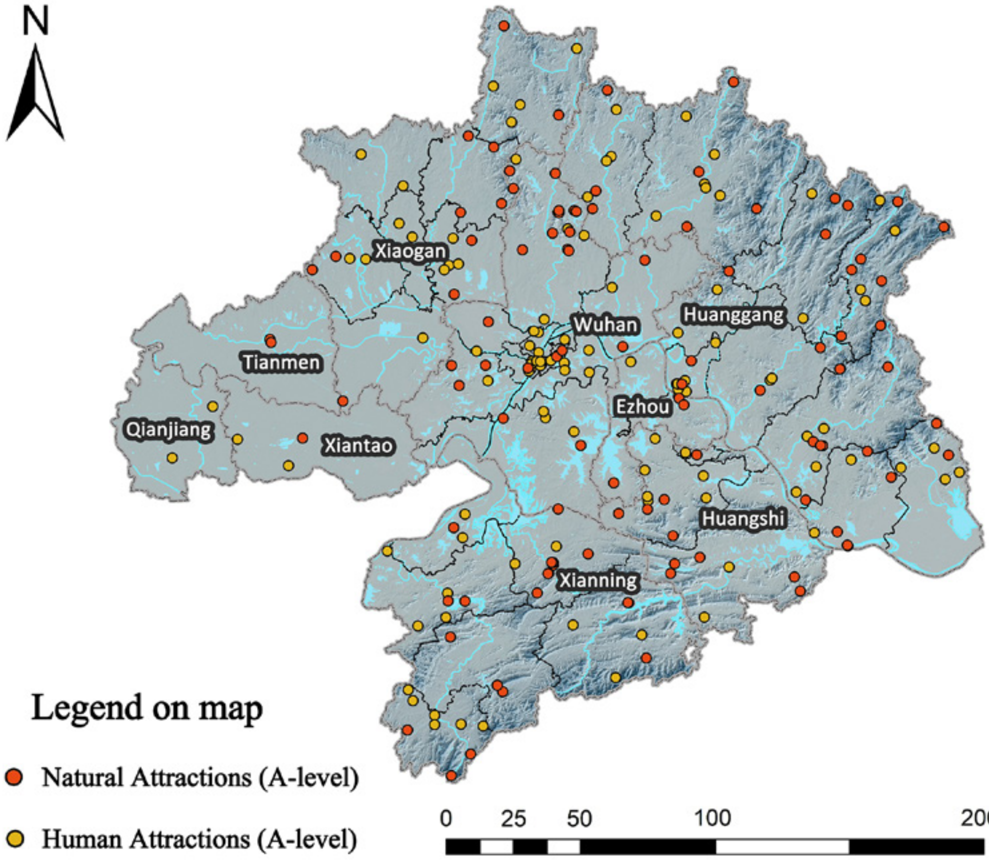

Figure 2. Location of Tourist Attractions in WUA (National A-level of China)

2.3. DESIGN OF THE STUDY

The study design was divided into two aspects: spatial structure characteristics and road traffic accessibility of the tourist attractions. The tourist attraction's spatial distribution and pattern were simulated using Average Nearest Neighbour (ANN) and Kernel Density Estimation (KDE) analysis.

ANN analysis measured the geospatial distribution and the proximity of point elements to each other in the regional space [23]. The Average Nearest Neighbour Ratio (ANN-R) was calculated as the observed average distance divided by the expected average distance, which was used to measure the distribution of point elements in geographic areas [24]. ANN-R less than 1 indicated that the distribution was a cluster, greater than 1 indicated that the distribution was discrete and equal to 1 indicated that the distribution was random [25]. The math expression of the existing model was as follows.

$$R = \frac{\bar{D}_o}{\bar{D}_e} \quad (1)$$

In the above expression (1), the observed average distance was the average distance between the tourist attractions point and the centroid of its nearest neighbor point, defined as $\bar{D}_o$. The expected average distance was the average distance in the

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random distribution of each tourist attraction point, defined as $\bar{D}_e$. The Average Nearest Neighbour Ratio (ANN-R) was defined as R.

Kernel Density Estimation (KDE) analysis assumed that within a certain spatial range, a certain object could occur at any geographical location, but the probability of occurrence differed at each spatial site [26]. Estimating probability density values based on the distance between the element to be assessed and the sample element [27], KDE converted discrete points in a region into a continuous density map based on a cell [28]. It could provide a clear visual representation of the geospatial posture of the A-level tourist attractions in WUA. Using the spatial property of the data sample to explore its spatial evolution trend helped reveal the spatial concentration of the tourist attractions [29]. The math expression of the existing model was as follows.

$$F(x) = \frac{1}{Nh}\sum_{i=1}^{n} K_n\left(\frac{x - x_i}{h}\right) \quad (2)$$

In the above expression (2), $F(x)$ was the estimated density function at spatial location x. N was the number of tourist attractions points in WUA. h was the bandwidth that controlled the degree of smoothing and the effect range for the kernel function [30]. K was the kernel function for the spatial weights. $x - x_i$ was the distance between data sites x and x_i.

The traffic access time was related to the average speed of the different road classes, and the time cost of the highway access was quantified based on a proportional relationship (Table 1). The traffic access time was constructed using Weighted Network Analysis to measure the accessibility between tourist attractions and traveler origin and further using Network Analysis to measure the accessibility between different tourist attractions. The results were visualized using Inverse Distance Weight (IDW).

Table 1. Time Cost of Traffic Access to Major Road Networks in China

Highway Classification	Road Speed (km/h)	Time Cost (min)
Expressway	100	0.60
National Highway	80	0.75
Provincial Highway	60	1.00
County Highway	40	1.50
Township Highway	30	2.00
Other Highways	20	3.00

Note: Road driving speed regarding the "Technical Standard Highway Engineering of the People's Republic of China (JTGB01-2003)" and related studies.

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Traffic accessibility was an indicator of the extent to which one element was connected to other elements. To better measure the accessibility between the tourist attractions and traveler origin, the travel intentions of tourists were not only considered in terms of spatial location and transport networks but also in terms of population, attractions level and accessibility time [31]. Using the weighted average access time of existing scholars' model to measure the road traffic accessibility between the tourist attractions and traveler origin by weighting total resident population, GDP and national attractions assessment indicators [8, 32]. Due to the reversible road network movements, using the tourist attraction site as the origin point and defined it as x, and the traveler origin site as the destination point and defined it as y. The math expression of the existing model was as follows.

$$Mxy = \sqrt[3]{Py \times Gy \times Lx} \quad (3)$$

$$Axy = \sum_{y=1}^{n} (Txy \times Mxy) / \sum_{y=1}^{n} Mxy \quad (4)$$

The above expression (3) was explored the weight of tourist attractions and traveler origin. P_y was the total resident population of the traveler origin site (y). Gy was the total GDP of the traveler origin site (y). Lx was the national assessment level of the tourist attraction site (x). The above expression (4) was used to calculate the average accessibility time between the tourist attraction site (x) and the traveler origin site (y) after weighting. Axy was the average weighted access time between the tourist attraction site (x) and the traveler origin site (y). n was the total number of the traveler origin site (y) (the geographical location of the traveler origin site was represented by the administrative location of the local government). Txy was the minimum access time cost between the tourist attraction site (x) and the traveler origin site (y). Mxy was the weighted result in the expression (3).

How to effectively organize a reasonable intra-city tourism spatial structure and routes according to the characteristics of tourist flow combined with the distribution of tourism resources was the key challenge to be solved in urban tourism development and planning [33]. Tourists sometimes would not return directly to their homes or hotels after arriving at one tourist attraction but continue traveling to another. Hence, this paper continued to measure the accessibility between different tourist attractions based on the movement trajectories of tourists. The road traffic accessibility of different tourist attractions was determined by measuring the average access time from one tourist attraction to another in the region [34]. The results of less average access time indicated the tourist attraction in the area with advantageous locations and more convenient accessibility for tourists [35]. Due to the reversible road network movements, defining two different tourist attraction sites as i and j. The math expression of the existing model was as follows.

$$Aij = \sum_{j=1}^{n} Tij/n \quad (5)$$

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In the above expression (5), it explored the average accessibility time between tourist attractions. Tij was the minimum access time cost between one tourist attraction (i) and another tourist attraction (j) through the road networks. n was the total number of tourist attractions in the region.

3. RESULTS AND DISCUSSIONS

3.1. SPATIAL STRUCTURE OF A-LEVEL TOURIST ATTRACTIONS

3.1.1. AVERAGE NEAREST NEIGHBOUR ANALYSIS OF TOURIST ATTRACTIONS

Based on the mathematical expression (1), the Average Nearest Neighbour (ANN) analysis measured the observed average distance and expected average distance for the A-level tourist attractions of WUA. The Average Nearest Neighbour Ratio (ANN-R) was obtained as 0.892 for natural attractions, 0.764 for human attractions and 0.766 for all attractions (Table 2). The results showed that the spatial distribution of different tourist attractions showed clustering under the condition of passing the significance test. The human attractions had the highest degree of clustering, while the natural attractions had the lowest.

Table 2. Average Nearest Neighbor (ANN) Results of Tourist Attractions in WUA

Classification	Natural Attractions (A-level)	Human Attractions (A-level)	All Attractions (A-level)
Number of Attractions/individual	94	120	214
Observed Average Distance/m	12250.5340	9367.0158	7419.9275
Expected Average Distance/m	13726.5459	12252.6485	9682.9361
Average Nearest Neighbour Ratio	0.892470	0.764489	0.766289
Z-Score	-1.994451	-4.935516	-6.540590
Distribution Trend	Cluster Distribution	Cluster Distribution	Cluster Distribution

3.1.2. KERNEL DENSITY ESTIMATION ANALYSIS OF TOURIST ATTRACTIONS

Based on the mathematical expression (2), the Kernel Density Estimation (KDE) analysis was used to generate a kernel density distribution map and identify spatial distribution hotspots of the tourist attractions (Figure 3). The overall trend of the A-

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level tourist attractions showed multiple core-periphery structures. The core high-value areas of kernel density were mainly distributed in the central urban area of Wuhan, while the sub-high-value areas were distributed in the surrounding regions of Xiaogan, Huanggang, Ezhou and Xianning.

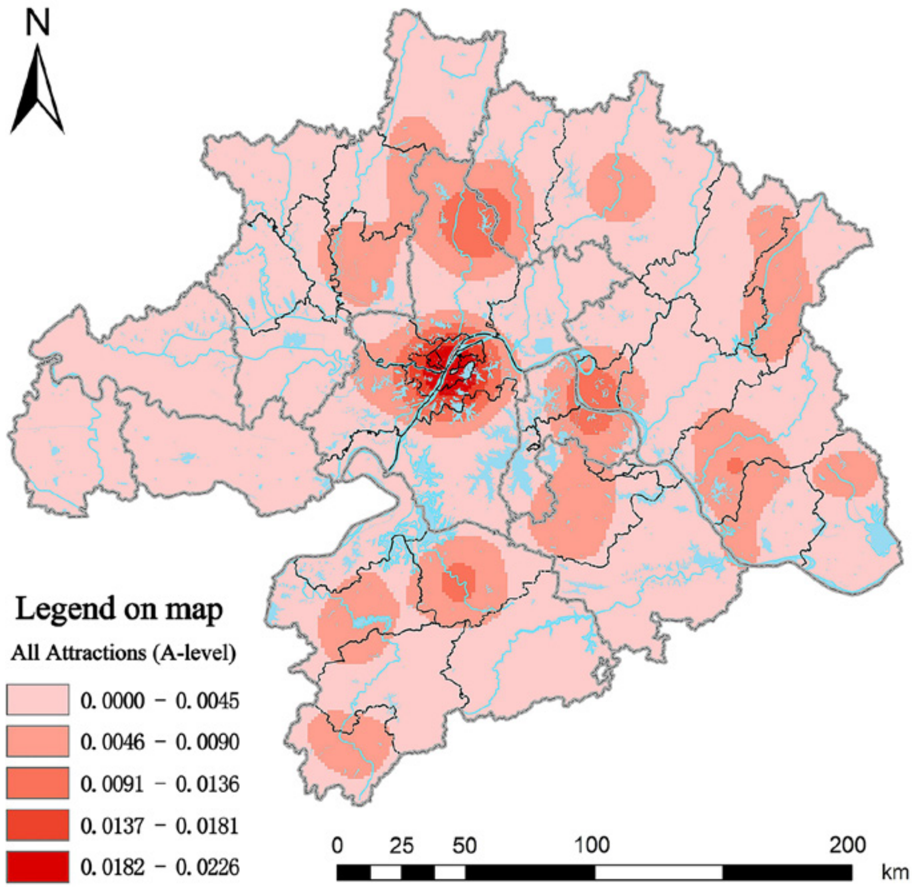

Figure 3. Kernel Density Estimation (KDE) Results for All Attractions in WUA

The natural and human attractions of WUA showed a core-periphery structure (Figure 4). The degree of core-density clustering was more significant in human tourist attractions than in natural tourist attractions. However, the core-density hierarchy of natural tourist attractions was more complex than that of human tourist attractions. The high core density areas of the natural tourist attractions were present in Wuhan Huangpi within WUA's northern part. The sub-high core density areas were presented in Xianning and Huangshi in WUA's southern region. The distribution results were closely related to the topography because the topography of the northern, southern and eastern parts of WUA was mainly mountainous and hilly. The unique natural landscape was more conducive to developing distinctive natural tourist attractions. To a certain extent, the shortage of natural tourist attractions in WUA's western part was due to the flat local terrain and the human farming culture of Jianghan Plain. The high core density of human tourist attractions was present in the central urban area of Wuhan and showed a very significant clustering compared to other surrounding areas. The distribution of human tourist attractions was related to Wuhan's deep historical heritage and developed economic level as a famous Chinese historical and cultural city.

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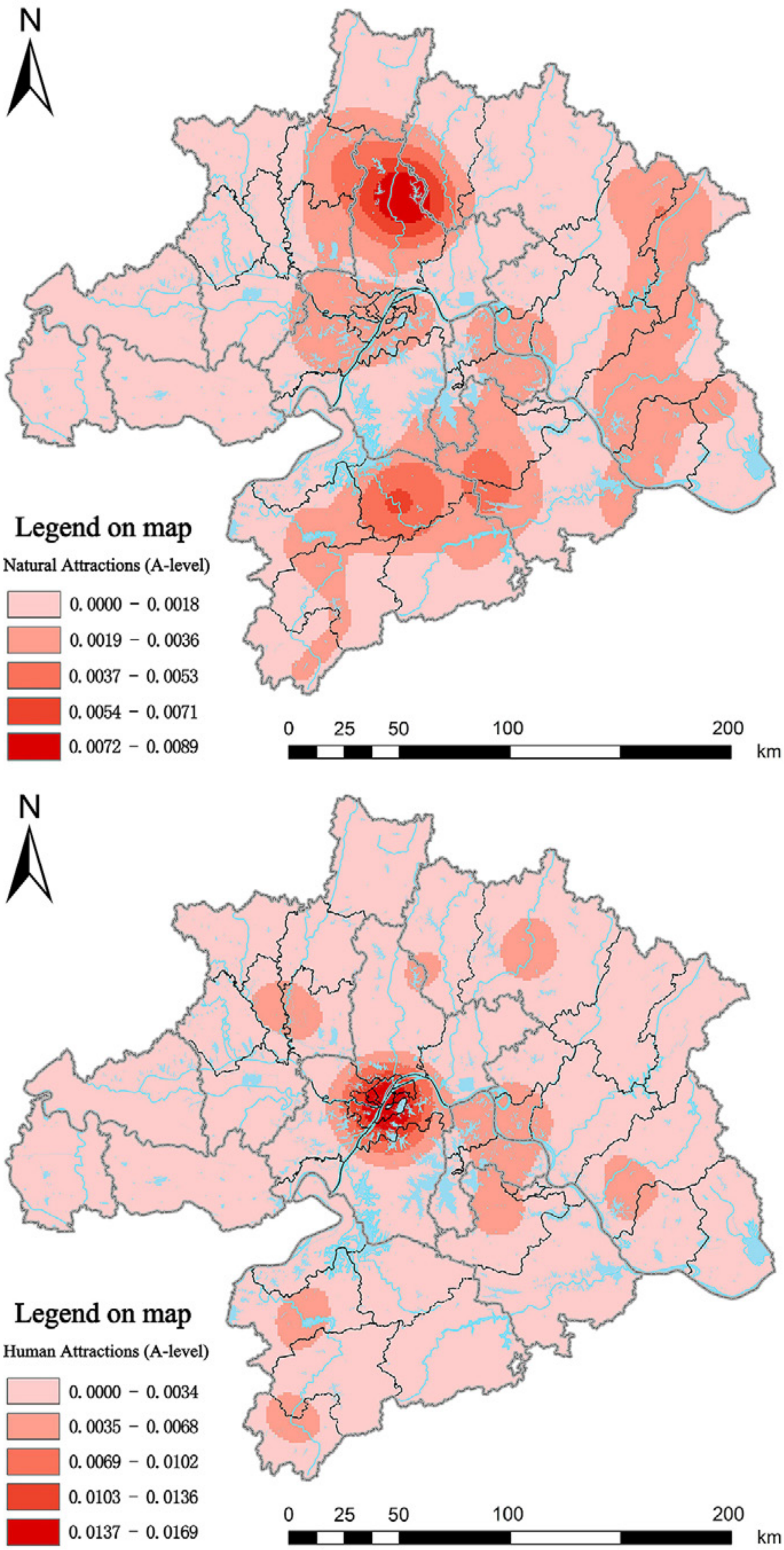

Figure 4. Kernel Density Estimation (KDE) Results for Natural and Human Attractions in WUA

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3.2. ROAD TRAFFIC ACCESSIBILITY OF A-LEVEL TOURIST ATTRACTIONS

3.2.1. ROAD TRAFFIC ACCESSIBILITY ANALYSIS BETWEEN TOURIST ATTRACTIONS AND TRAVELER ORIGIN

The impact of the resident population, total GDP, and tourist attractions assessment on traffic accessibility was relevant [32]. Because economically developed regions usually had higher per capita income and more government investment in developing tourism infrastructure. The high numbers of resident population meant there were more potential tourists of traveler origin. In addition, higher assessment levels of tourist attractions indicated better infrastructure provision, accommodation and catering services in the vicinity. The mathematical expressions (3) and (4) were used to measure the weighted average accessibility time between tourist attractions and traveler origin (Table 3).

Table 3. Statistical Results of Average Traffic Accessibility Time between Tourist Attractions and Traveler Origin in WUA

Road Traffic Accessibility Time	Between Natural Attractions and Traveler Origin (A-level)	Between Human Attractions and Traveler Origin (A-level)	Between All Attractions and Traveler Origin (A-level)
0.0 ≤ T ≤ 1.5	5 (5.32%)	21 (17.50%)	26 (12.15%)
1.5 < T ≤ 2.0	19 (20.21%)	29 (24.17%)	48 (22.43%)
2.0 < T ≤ 2.5	38 (40.42%)	37 (30.83%)	75 (35.05%)
2.5 < T ≤ 3.0	27 (28.73%)	23 (19.17%)	50 (23.36%)
3.0 < T ≤ 3.5	3 (3.19%)	9 (7.50%)	12 (5.61%)
3.5 < T	2 (2.13%)	1 (0.83%)	3 (1.40%)
Total	94 (100%)	120 (100%)	214(100%)

The results showed that the weighted average accessibility time from the tourist attractions to traveler origin (48 county-level administrative units under WUA) ranged from 1.24h to 3.82h (Figure 5), with a mean value of 2.21h. The road traffic accessibility between tourist attractions and traveler origin indicated a spatial centrality trend with Wuhan as a core circle structure. In general, WUA had better east-west accessibility than north-south accessibility.

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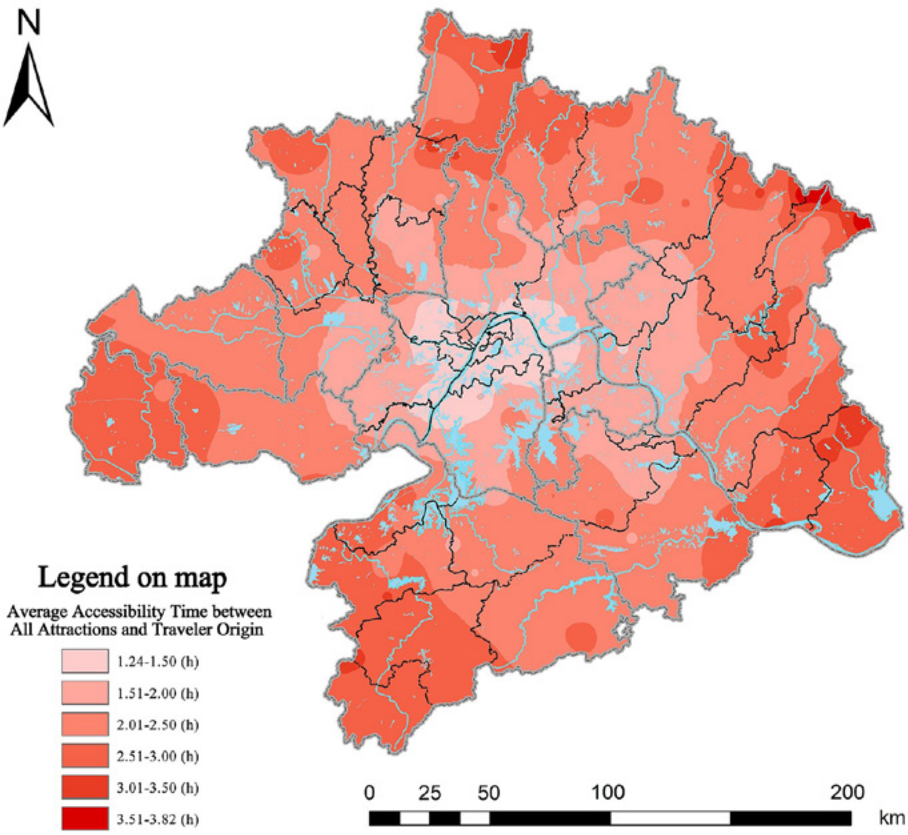

Figure 5. IDW Visualization Results of Average Accessibility Time between All Attractions and Traveler Origin in WUA

Road traffic accessibility from the natural and human tourist attractions to traveler origins under the WUA administration showed a core-periphery structure (Figure 6). The areas where the average access time of road traffic accessibility was less than 2h were mainly concentrated in Wuhan, and the accessibility of human tourist attractions was better than that of natural tourist attractions. The road traffic accessibility of tourist attractions in Ezhou, Huangshi, Huanggang, Xiaogan, Xianning, Qianjiang, Xiantao and Tianmen mainly was between 1.5h and 3h. The multiplicative difference between some of the tourist attractions and traveler origin in WUA reached more than three triples, representing a significant regional difference in traffic accessibility. In addition, some areas had poor accessibility between tourist attractions and traveler origin in WUA, such as the Dabie Mountains in the northeast region of WUA.

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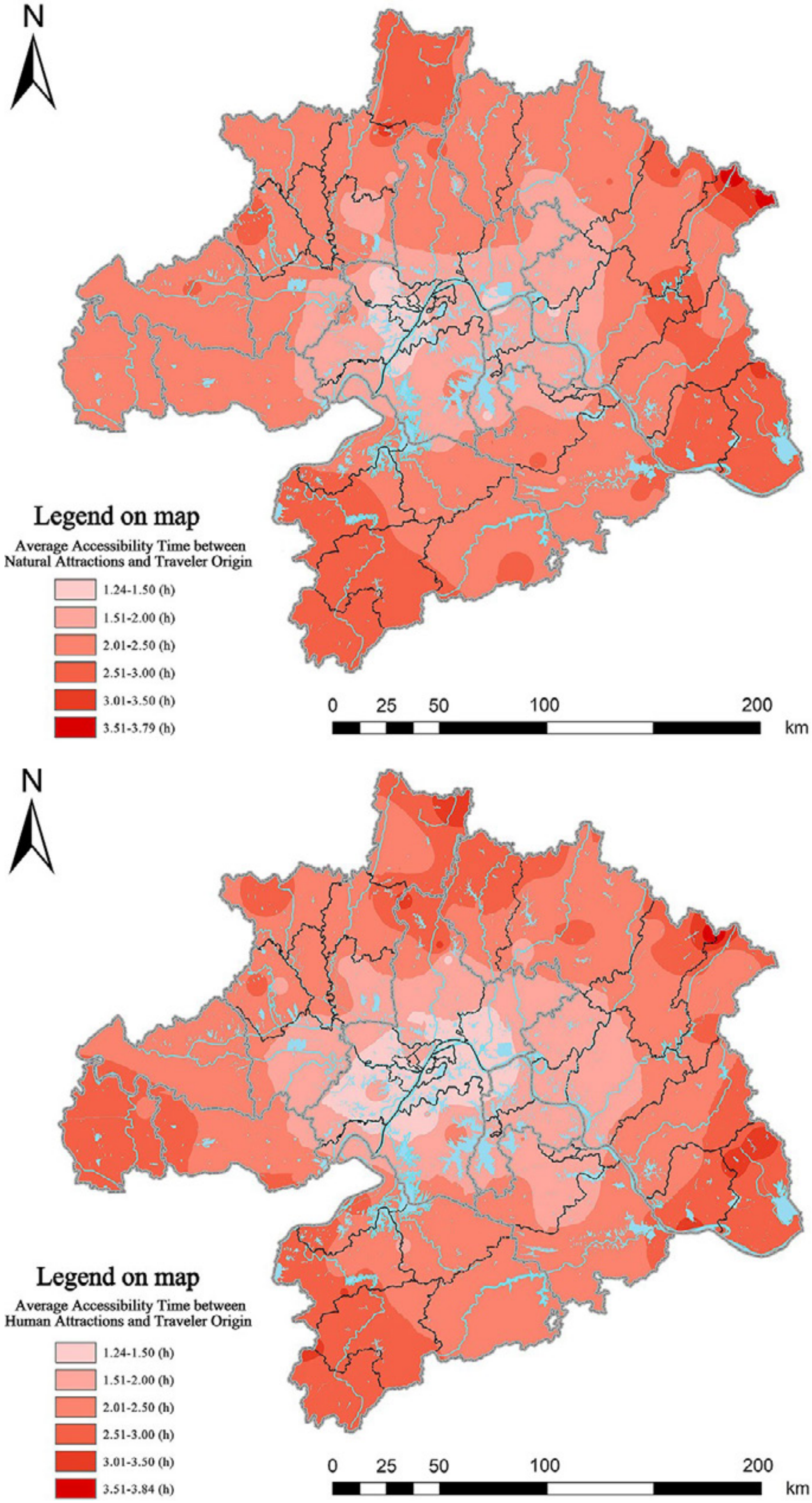

Figure 6. IDW Visualization Results of Average Accessibility Time between Natural and Human Attractions and Traveler Origin in WUA

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3.2.2. ROAD TRAFFIC ACCESSIBILITY ANALYSIS BETWEEN DIFFERENT TOURIST ATTRACTIONS

The mathematical expression (5) was used to measure the average access time between different tourist attractions (Table 4). The average accessibility time between different tourist attractions ranged from 1.45h to 3.62h, with an average of 2.27h.

Table 4. Statistical Results of Average Traffic Accessibility Time between Different Tourist Attractions in WUA

Road Traffic Accessibility Time	Between Natural Attractions (A-level)	Between Human Attractions (A-level)	Between All Different Attractions (A-level)
0.0 ≤ T ≤ 1.5	0 (0%)	2 (1.67%)	2 (0.93%)
1.5 < T ≤ 2.0	17 (18.09%)	44 (36.67%)	61 (28.51%)
2.0 < T ≤ 2.5	46 (48.94%)	38 (31.67%)	84 (39.26%)
2.5 < T ≤ 3.0	25 (26.59%)	25 (20.83%)	50 (23.36%)
3.0 < T ≤ 3.5	5 (5.32%)	10 (8.33%)	15 (7.01%)
3.5 < T	1 (1.06%)	1 (0.83%)	2 (0.93%)
Total	94 (100%)	120 (100%)	214 (100%)

The road traffic accessibility among all different tourist attractions showed a circle structure with Wuhan as the core with evident centrality (Figure 7). Wuhan and Ezhou had higher road traffic accessibility than other regions in WUA, and the tourist attractions with poorer road traffic accessibility were mainly located in the western part of WUA and the southwestern part of WUA. Its insufficient road traffic accessibility was due to fewer nearby tourist attractions and its more remote location. The average access time with the best traffic accessibility was 2.5 times higher than the worst, showing a noticeable difference in regional accessibility.

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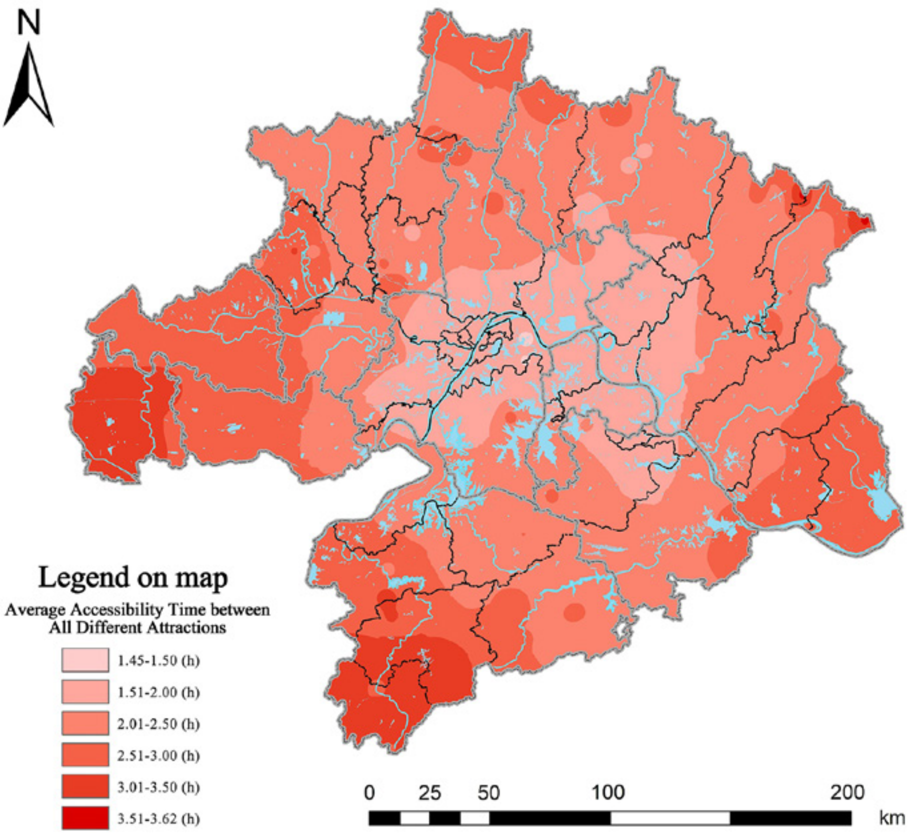

Figure 7. IDW Visualization Results of Average Accessibility Time between All Different Attractions in WUA

The spatial pattern for road traffic accessibility of natural tourist attractions gradually surrounded Wuhan and Ezhou to the periphery. The average access time of natural tourist attractions ranged from 1.50h to 3.54h, with an average value of 2.34h. The road traffic accessibility of human tourist attractions surrounded in a gradient from Wuhan and Ezhou to the surrounding areas, and the road traffic accessibility in the central part of WUA was significantly higher than in the surrounding areas. The average access time for human tourist attractions ranged from 1.45h to 3.65h, with an average value of 2.23h. The results indicated that the road traffic accessibility between different human tourist attractions was better than between different natural tourist attractions (Figure 8). Because the distribution of human tourist attractions was relatively concentrated, mainly in areas with excellent historical development and dense road networks. However, the distribution of natural tourist attractions was more dispersed, mainly in hilly and mountainous regions of WUA endowed with natural resources but not easily reachable.

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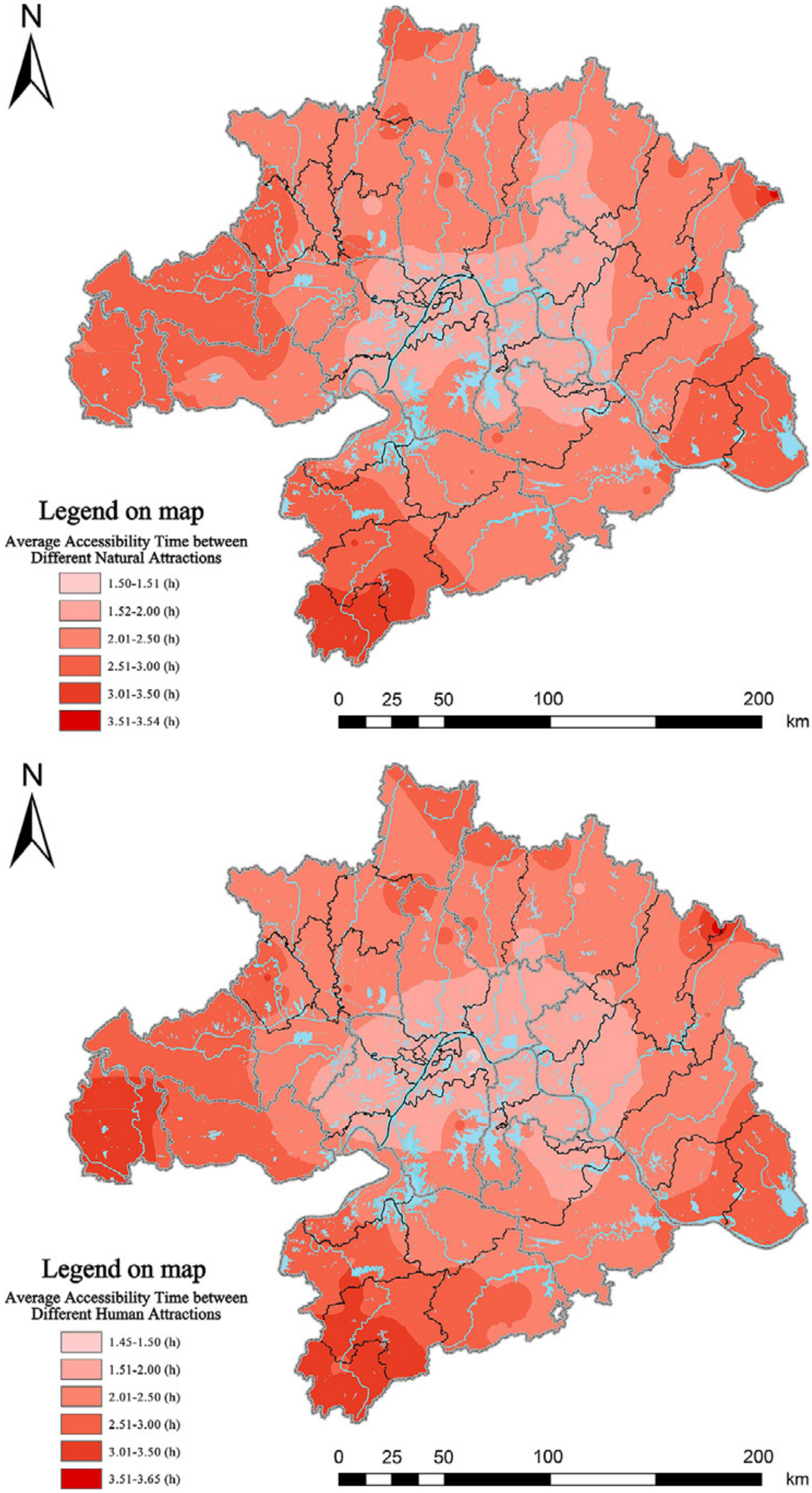

Figure 8. IDW Visualization Results of Average Accessibility Time between Different Natural Attractions and Average Accessibility Time between Different Human Attractions in WUA

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4. CONCLUSIONS

4.1. CONCLUSION

In the context of regional travel of short distances becoming more common, this paper used a combination of mathematical statistics and spatial analysis to explore the spatial structure distribution and to measure the road traffic accessibility of the A-level tourist attractions within WUA. The spatial distribution of tourist attractions in WUA showed a core-periphery structure in general. Different spatial distribution patterns of tourist attractions both indicated clustering. The spatial clustering of human tourist attractions was the highest, and the spatial clustering of the natural tourist attractions was the lowest. The accessibility of WUA's tourist attractions and traveler origin generally showed a core-periphery structure with Wuhan as the core. The accessibility between different tourist attractions of WUA showed a core-periphery structure with Wuhan and Ezhou as the core. The results exhibited significant centrality and regional differences in road traffic accessibility. The road traffic accessibility of human tourist attractions was better than that of natural tourist attractions.

The spatial distribution and road traffic accessibility of tourist attractions in WUA showed a circle structure centered on Wuhan, aligning with the general regional development rule. However, considering the coordinated development of the region, the A-level tourist attractions resources in western areas of WUA were inadequate, and the accessibility of the north-south direction in WUA was weaker than that of the east-west direction in WUA. Human tourist attractions were mainly concentrated in urban areas with high connectivity and intensive road networks. But natural tourist attractions were separated from traveler origin and other attractions in WUA. Most were in mountainous and hilly areas with poor accessibility, which could attract more tourists with better road networks and traffic infrastructure.

4.2. LIMITATION AND PROSPECT

In the background of the popularity of short-distance travel after COVID-19, this paper empirically analyzed the accessibility of A-level tourist attractions in WUA by means of the road traffic accessibility evaluation model. Due to the lack of consideration of some intra-city road data (the standards and levels of intra-city road data in different cities within WUA were not uniform), the results of tourist attractions accessibility calculations might differ from the actual accessibility level to a certain extent. In addition, the road accessibility measurement assumed a uniform road speed without considering factors such as the degree of mountainous terrain, traffic congestion and subjective choice of travel routes, and it was hoped that some scholars could make a breakthrough for the limitation problem in the future.

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5. DATA AVAILABILITY

All the data for this study is available upon request to the author.

6. CONFLICT OF INTEREST

The authors declare that the research has no financial or personal relationships with other people or organizations that can interfere with it.

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