International Journal of Geo-Information

MDPI

Article

Identifying the Hierarchical Structure of Nighttime Economic Agglomerations Based on the Fusion of Multisource Data

Weijie Wan [1,2,3,4], Hongfei Chen [1,2,3,4,*], Xiping Yang [1,2,3,4], Renda Li [1,2], Yuzheng Cui [1,2] and Yiyang Hu [1,2]

[1] School of Geography and Tourism, Shaanxi Normal University, Xi'an 710119, China; wanweijie@snnu.edu.cn (W.W.); xpyang@snnu.edu.cn (X.Y.); lrdgis@snnu.edu.cn (R.L.); yuzheng-cui@snnu.edu.cn (Y.C.); hyylinkin7@snnu.edu.cn (Y.H.)
[2] Shaanxi Key Laboratory of Tourism Informatics, Xi'an 710119, China
[3] Shaanxi Province Tourism Informatization Engineering Laboratory, Xi'an 710119, China
[4] Shaanxi Province Digital Culture and Tourism Technology and Application Laboratory, Xi'an 710119, China
* Correspondence: chenhongfei@snnu.edu.cn; Tel.: +86-13572858318

Abstract: Nighttime economic development is an important driving force in urban economic development, and identification of the levels and boundary ranges of nighttime economic agglomerations is an important part of the management of the nighttime economy. Previous studies have been limited by the use of a single data source to identify nighttime economic agglomerations. To address this limitation, multisource data fusion was used in this study to integrate nighttime lighting data, point of interest data, and check-in data and to assess the nighttime economy more comprehensively from the perspectives of both providers and receivers in the nighttime economy. To identify the hierarchical structure and boundaries of nighttime economic agglomerations accurately, a two-step method was used to identify local hotspots of the nighttime economy, divide the nighttime economic agglomerations into levels, and explore the spatial distribution and functional characteristics of different levels of nighttime economic zones. Comparative experiments showed the method used in this study to be rational and accurate. The methods and results of this study can provide a more comprehensive approach to the precise identification of nighttime economic agglomerations and guidance for the future planning, rational development, and management of nighttime economic agglomerations.

Keywords: nighttime economic agglomerations; multisource data; hotspot detection; quantitative identification

check for updates

Citation: Wan, W.; Chen, H.; Yang, X.; Li, R.; Cui, Y.; Hu, Y. Identifying the Hierarchical Structure of Nighttime Economic Agglomerations Based on the Fusion of Multisource Data. *ISPRS Int. J. Geo-Inf.* **2024**, *13*, 188. https://doi.org/10.3390/ijgi13060188

Academic Editors: Wolfgang Kainz and Jamal Jokar Arsanjani

Received: 14 March 2024
Revised: 31 May 2024
Accepted: 5 June 2024
Published: 6 June 2024

Copyright: © 2024 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

1. Introduction

The concept of the "nighttime economy", proposed by the British scholar Montgomery in the 1990s [1], was initially an economic concept related to the phenomenon of "empty streets" in urban centers and was an important part of the British urban regeneration plan. With scholars' in-depth research on the nighttime economy, the meaning of nighttime economy has been extended to nighttime business, nighttime consumption, and nighttime social activities. Specifically, the nighttime economy refers to activity that occurs between 18:00 on one day and 6:00 the next morning [2], including both the economic attributes of production or consumption behaviors dominated by services and entertainment and the social attributes of various activities and behaviors carried out in public places at night [3], such as shopping, catering, leisure, education, and sports. Current research on the nighttime economy mainly focuses on the fairness of nighttime economic distribution [4–6]; nighttime public safety and environmental pollution problems [6–8]; the development status of the nighttime economy, its role, and enhancement strategies [3,9]; and nighttime tourism-related problems [10,11].

In the 21st century, with the development of China's cities and the improvement of its infrastructure, the living standards of residents have improved. This has led to changes in their way of life and work. Because of busy work schedules during the day, it is difficult for

people to satisfy their consumption needs, such as dining, shopping, and leisure; therefore, an increasing number of residents are choosing to engage in consumption activities at night. The expansion of the nighttime economy has enriched residents' lives, stimulated consumption, and significantly shaped the structure of urban activity space [4,12]. At the same time, under the impact of the COVID-19 epidemic in recent years, increasing jobs, expanding domestic demand, and promoting consumption have become focuses of urban economic development. The nighttime economy prolongs the duration of economic activities, prolongs the length of stay of tourists, and increases the rate of employment [13]. The nighttime economy has become increasingly important in promoting economic growth by increasing consumption by residents. Promoting the nighttime economy has been elevated to a strategic level as an important initiative to "stimulate the potential of a new round of consumption upgrading" in China. The combination of an urban nighttime consumption space and nighttime activities forms a nighttime economic agglomeration. The study of the distribution and structural characteristics of nighttime economic agglomerations is of great significance in recognizing the status quo of nighttime economic development and improving the efficiency of the nighttime economy, as well as in providing guidance for the regulation and control of the urban nighttime economy.

Previous studies on nighttime economic agglomerations fall into the following general categories: research on the distribution characteristics of nighttime economic agglomerations, with nighttime economic carriers or hotspots for the distribution of human nighttime activities as the objects of study [14,15]; research on methods for quantitatively identifying the scope and boundaries of agglomerations [16]; and research on the development of the nighttime economy with administrative divisions or streets as the basic units of agglomeration [17]. Nevertheless, most previous research has used a single criterion to determine the extent of agglomeration or to investigate the internal characteristics of agglomerations; it has not entailed determining the hierarchical structure of economic agglomerations at night. To further explore the spatial and functional interactions of various nighttime economic clusters, the hierarchical structure of clusters can be used to evaluate the spatial distribution patterns of clusters at the same level, as well as the spatial containment relationships of different clusters and the attributes of each level [18]. Commonly used techniques for identifying hierarchical structures include clustering algorithm grading [19], the local contour tree approach [20], and hotspot detection models [21]. The drawback of the clustering approach is that the parameters have a significant impact on both the spatial scope and the number of class clusters [22]. It is not possible to quantify the boundary values of the various classes using the local contour tree approach because there is no obvious way to determine parameters, such as the interval between contour lines and the value of starting contour lines.

The hotspot detection model was used in this study to identify local extreme spots within the study area quantitatively. Using the hotspot level as the dividing line for each class and grading the extremes discovered, it is possible to classify data objectively [23]. However, the hotspot detection model is limited to identifying localized extreme values and does not consider the possibility that extreme value points can be used as hotspots in the entire study area [24]. Consequently, some low-value hotspots may be mistakenly identified, leading to a large overall area for each grade. To mitigate this shortcoming of the hotspot detection model, an appropriate spatial statistical technique must be implemented to ascertain the approximate hot zone range throughout the study region. Subsequently, extreme value points must be filtered to identify statistically significant hotspots, which were then used to determine the boundary values at each level.

New geo-big data, represented by point of interest (POI) data [25], location check-in data [26,27], and nighttime lighting data [28,29], were used extensively to identify nighttime economic agglomerations. Nighttime brightness is an indicator of the spatial and hierarchical structure of a city [30] and is useful in research on urban space, socioeconomic status, and digital economic development [13]. In previous nighttime economic studies, numerous scholars have used nighttime light brightness to characterize nighttime economic

intensity. However, nighttime lighting data have the following limitations: (1) there is a bloom effect in nighttime lighting data that leads to bias in problems related to socioeconomic estimation [31]; (2) the proximity of nighttime lighting brightness to human activity may be weak in some parts of a city, as with city lights and streetlamps that are not affected by human activities [32]; (3) many nighttime activity sites are indoors and do not produce external light. These limitations make it difficult to use nighttime light data alone to represent nighttime economic levels. POI data can identify the specific locations of nighttime economic carriers, and combining POI data with nighttime lighting data can mitigate the nighttime lighting overflow problem and road impacts [33,34]. However, nighttime light brightness and POI datasets consider nighttime economic intensity from the perspective of nighttime economic providers, and using these two types of datasets does not establish the connection between crowd activities and nighttime economic space; that is, they do not take into account the recipients of the nighttime economy.

As a type of social media, Weibo has become one of the main Internet user activities in China [35]. Social media check-in data can directly reflect the intensity of human activities [36] and have been shown to be reliable in studying socioeconomic problems [37]. A higher degree of crowd aggregation indicates that more nighttime consumption behaviors may be generated. Therefore, the density of Weibo check-ins can serve as a measure of the nighttime economy from the perspective of nighttime economic recipients and can play a complementary role for nighttime bazaars and indoor activity venues that cannot be accurately identified from nighttime lighting and POI data. Measurement results obtained using a single data source may be partial and biased, whereas multisource data fusion is a comprehensive and effective measurement method [38,39]. Nighttime lighting, POI, and Weibo check-in data can be combined to more accurately and comprehensively estimate or map the metrics of the nighttime economy in terms of both providers and recipients of the nighttime economy and explore the distribution characteristics of nighttime economic agglomeration.

To summarize, to supplement the limitations of individual data types and methods for quantitative identification of nighttime economic agglomerations, this study took the main urban area of Xi'an as an example and integrated nighttime lighting data, POI data, and check-in data to construct what we term the "QPW composite index", which provides data support for nighttime economic agglomeration measurements from a more comprehensive perspective. A two-step approach was then used to identify hotspots of nighttime economic activities. The first of the two steps was to use a hotspot detection model to extract local extreme points. The second step was to use the Getis-Ord Gi* index to determine the approximate range of hotspots in the study area and screen the extreme points within the hotspot area as hotspots. Finally, the identified hotspot values were used as the basis for the hierarchical division of nighttime economic agglomerations, which were expressed visually using contour lines and hierarchical structure maps reflecting the current status of agglomeration development in terms of the spatial distribution and structural characteristics of different hierarchical agglomerations (Figure 1).

The main contributions of this study are as follows: (1) demonstration of the use of multisource data fusion, which takes into account both the providers and receivers of the nighttime economy, overcomes the limitations of using a single type of dataset as in previous studies, and makes the results of the study more reliable; and (2) quantitative identification of the hierarchical structure and spatial distribution of nighttime economic agglomerations and the spatial distribution results of different levels of night economic agglomeration, which can enable people to meet their social and economic needs as far as possible at the nearest destination [40]. From the perspective of planners, the results of this study can be used to refine the management and control of urban nighttime economic agglomerations and provide a basis for the reasonable layout of related supporting facilities and healthy development of the nighttime economy.

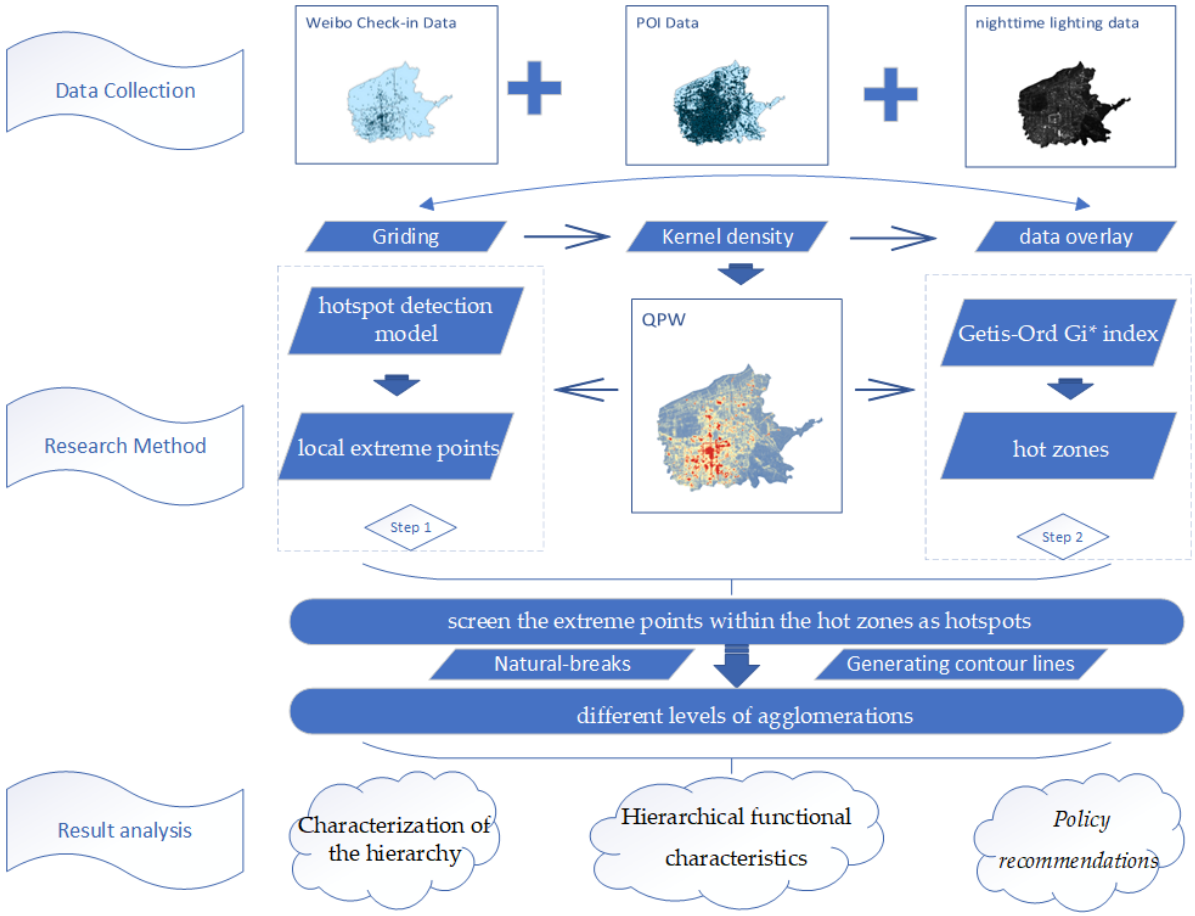


Figure 1. Technology roadmap.

2. Materials and Methods

2.1. Study Area

The capital of Shaanxi Province, Xi'an, serves as the hub of the Guanzhong Plain Urban Agglomeration, the Xi'an Metropolitan Area, a megacity, a national center, and a sub-provincial city. The municipal administration of Xi'an places a high value on the growth of the nighttime economy, enhances management services, and implements a number of laws and regulations to encourage and direct various market participants to engage in nighttime consumption. In June 2022, Xi'an unveiled six policies across many departments that support the outdoor economy and the nighttime economy. The identification of Xi'an's nighttime economic agglomeration has been the subject of few studies, and quantitative research has not been conducted to assist development decisions. Consequently, the key city districts of Xi'an, such as the Weiyang District, the Beilin District, and the remaining six municipal districts, were chosen as the focus of this study (Figure 2). The nighttime economic agglomeration was quantitatively analyzed and hierarchically identified.

2.2. Data Sources

The primary research data used in this study were road network data, Qimingxing-1 satellite nighttime light data, POI data, and Weibo check-in data. The road network data were sourced from the OpenStreetMap (OSM) open-source map website and used for the geometric correction of the data related to nighttime illumination. The following procedures were followed to gather and process the nighttime lighting data, POI data, and Weibo check-in data.

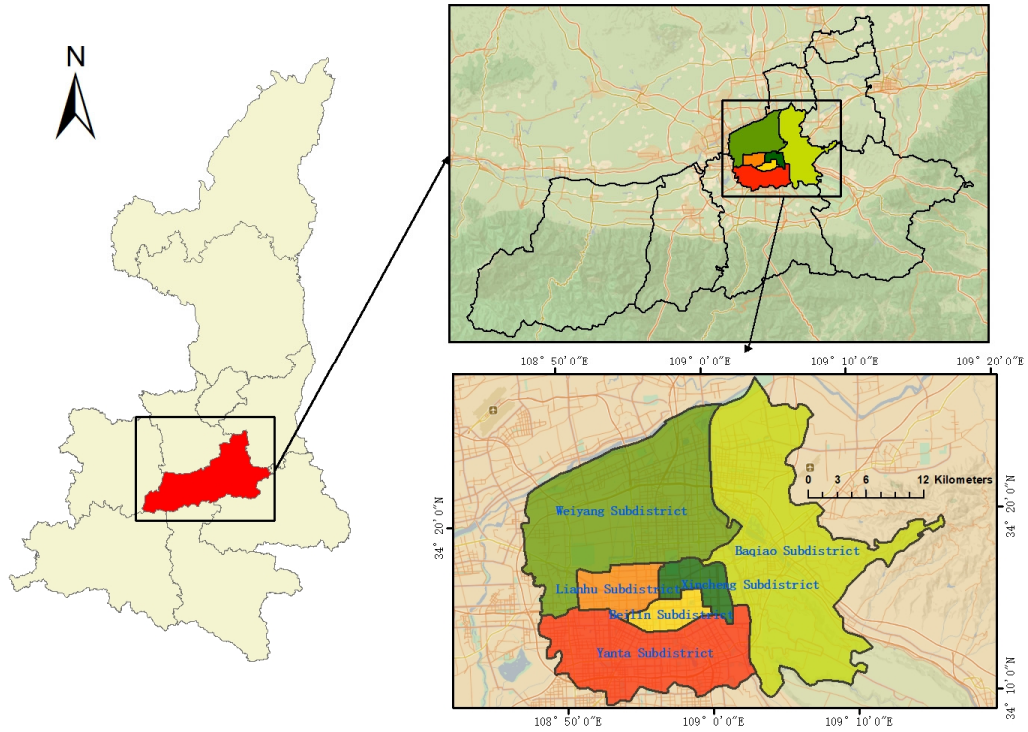


Figure 2. Overview map of the study area.

2.2.1. Nighttime Light Data

The nighttime lighting data used in this study were collected on 9 April 2022, by the Qimingxing-1 (QMX-1) satellite. QMX-1 can provide images with a spatial resolution of 25 m and a width of 50 km, which greatly reduces the problem of low resolution of commonly used nighttime light images and can effectively reflect urban details [41] (Figure 3a). OSM road network data were chosen to rectify the QMX-1 data because the latter were not geometrically rectified. A quadratic polynomial model was employed as the correction model, and 40 control points were selected for alignment within this range. The adjusted images were filtered to remove noise.

2.2.2. POI Data

The POI data used in this study, which consisted primarily of name, type, latitude, and longitude data, were obtained from the public "Gaode Map" platform in November 2022 (Figure 3b). Following data cleansing and coordinate conversion, the POI data were divided into eight categories based on the nature and attributes of nighttime economic activities and the National Economy Industry Classification Standard (NECS). These categories included dining, shopping, lodging, living services, sports, recreation, and sightseeing (Table 1).

Table 1. POI classification.

POI Category	Main Modes of Operation	Quantity	Percentage
Shopping	Supermarkets, convenience stores, malls, grocery stores, etc.	74,944	43.20%
Dining	Chinese food, foreign food, snacks, cakes and desserts, etc.	51,055	29.40%
Living Services	Laundromat, photographic printing, beauty salon, etc.	16,864	9.70%
Accommodation	Star hotels, express hotels, B&Bs, youth hostels, etc.	12,136	7%
Education	Educational institutions, vocational training, study rooms, etc.	10,401	6%
Sports	Gymnasiums, basketball courts, swimming pools, etc.	3010	1.70%
Recreation	Bars, KTVs, movie theaters, chess and card rooms, etc.	2898	1.60%
Sightseeing	Scenic spots, parks, playgrounds, cultural relics, etc.	1892	1%

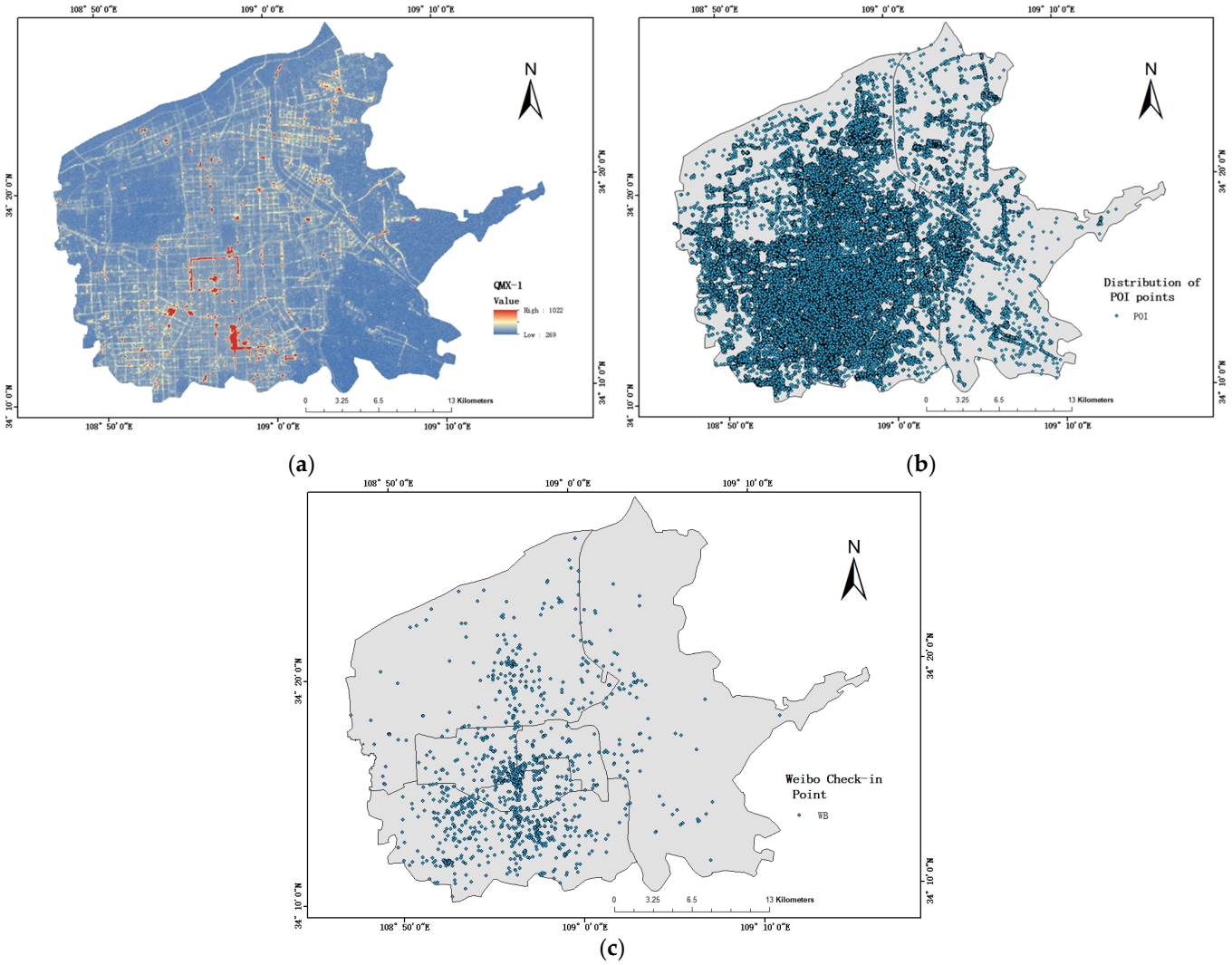


Figure 3. (**a**) QMX-1 nighttime light brightness data; (**b**) distribution of POI points; (**c**) distribution of Weibo check-in points.

2.2.3. Weibo Check-in Data

Weibo check-in data were obtained through the API interface provided by the Sina Weibo platform. The data included the user's name, check-in latitude and longitude, check-in time, and other information (Figure 3c). Weekly data for June 2022, which was less affected by the COVID-19 pandemic than some other months of 2022, were selected for use. The data were screened for check-ins between 18:00 and 6:00 the next day.

2.3. Research Methodology

The research methodology consisted of three components. The QPW composite index was constructed by integrating data from multiple sources. A two-step method was then used to identify hotspots of nighttime economic activity. Finally, a quantitative hierarchy of nighttime economic agglomeration based on the hotspots was developed. Details of each of these components of the research methodology are provided below.

2.3.1. QPW Composite Index Construction

1. Kernel density estimation

The spatial distribution states of the POI and Weibo check-in locations were determined using the kernel density estimate approach. The kernel density was calculated as follows:

$$P_i = \frac{1}{n\pi R^2} \times \sum_{j=1}^{n} K_j \left(1 - \frac{D_{ij}^2}{R^2}\right)^2, \quad (1)$$

where n is the number of data points j in the computational area, R is the bandwidth, K_j is the weight of data point j, and D_{ij} is the Euclidean distance between spatial points i and j. The bandwidth setting is mainly related to the analysis scale and characteristics of the geographical phenomena [42]. Based on this and relevant research in Xi'an [23] and combined with the walking activity range of various age groups in the city [43], 500 m was selected as the bandwidth used to generate the kernel density surface.

2. QPW composite index

To eliminate the effect of magnitude between different types of data, the kernel density values of the nighttime brightness values of the QMX-1, POI, and Weibo check-ins were normalized before synthesis using the following equation:

$$X' = \frac{(X - X_{min})}{(X_{max} - X_{min})}, \quad (2)$$

where X' is the normalized value, X is the original value, and X_{max} and X_{min} are the maximum and minimum values, respectively, in the data.

A weighted overlay of the three normalized values was then applied to construct the QPW composite index as follows:

$$QPW_i = w_1 \times QMX_i + w_2 \times POI_i + w_3 \times WB_i, \quad (3)$$

where QPW_i is the fused value of image i; QMX_i is the nighttime light luminance value of image i; POI_i and WB_i are the kernel density values of the POI and Weibo check-ins for image i, respectively; and w_1, w_2, and w_3 are three weights.

In terms of weight setting, this study argues that places with a high intensity of nighttime crowd activity may generate more nighttime consumption, so check-in data that can directly represent the activity density of nighttime economic recipients should be weighted more heavily. Some scholars have pointed out in related studies that nighttime light brightness and POI data are equally important in assessing nighttime economic issues [10]. Finally, considering that the microblog check-in data itself also have some bias in the form of the problem of crowd representation, combined with the comparison experiment, the weight of the check-in data should not be too large. Taking the above considerations into account, combining the characteristics of the three types of data, and referring to the relevant literature, the weights were set as follows: weight w_3 was set to 0.4, and w_1 and w_2 are each set to 0.3.

2.3.2. Extraction of Hotspots of Nighttime Economic Activities Based on the Two-Step Method

1. Hotspot detection model

Local extreme points within the research area were extracted using a hotspot detection model. The density field hotspot detection model is applied in the following main steps: (1) Using focus statistics in the ArcGIS 10.2 software [44], construct a neighborhood pixel maximum surface in the QPW composite index image, which is designed to detect extreme values within a local area and ultimately turn every pixel in the range into the highest value within the domain. (2) Use map algebra to perform an algebraic difference operation on the QPW image and the extraction result of the previous step, in which the pixel whose

algebraic difference between the two is zero, and the original pixel value corresponding to its location is the maximum value in the range. Thus, the purpose of this step is to obtain the location of the local maximum value. (3) Based on the location of the local extreme value, obtain the original value at the corresponding location in the QPW composite index image and the local extreme value. A schematic implementation of the method is shown in Figure 4.

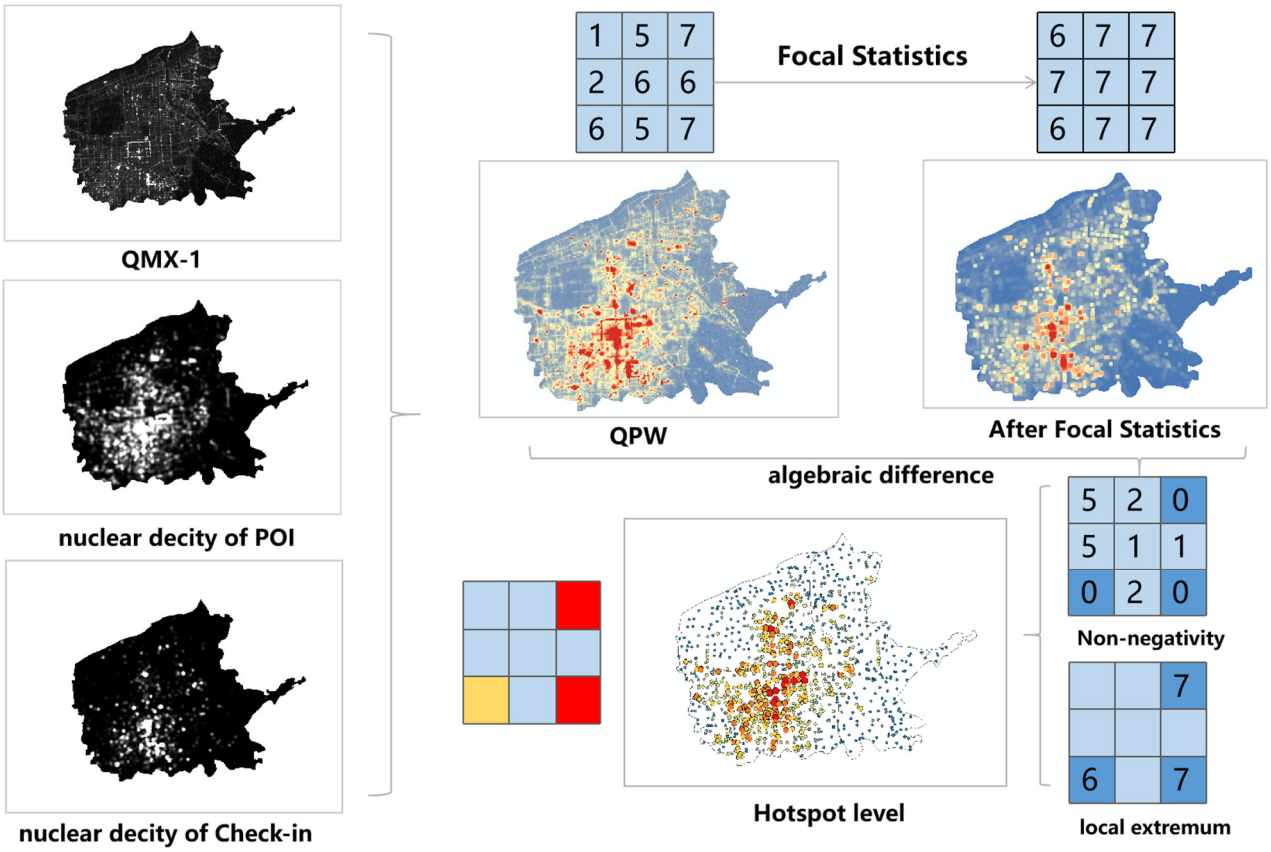


Figure 4. Flow of hotspot detection model implementation. The numbers in the grid in the figure represent different raster values, and different colors represent different values, the darker the color the greater the value.

2. The Getis-Ord Gi* Index

In the second step, the Getis-Ord Gi* index was used to identify the approximate extent of the agglomeration area to filter the hotspot values further:

$$G_i^* = \frac{\sum_{j=1}^{n} w_{i,j}x_j - \overline{X}\sum_{j=1}^{n} w_{i,j}}{S\sqrt{\frac{\left[n\sum_{j=1}^{n} w_{i,j}^2 - \left(\sum_{j=1}^{n} w_{i,j}\right)^2\right]}{n-1}}}. \quad (4)$$

x_j is the attribute value of element j, which in this paper is the corresponding QPW composite index value of the grid cell; n is the total number of grid cells divided in the study area; and $w_{i,j}$ is the spatial weight of elements i and j. Where $\overline{X} = \frac{1}{n}\sum_{j=1}^{n}\frac{x_j}{n}$ denotes the mean value of all cells, $S = \sqrt{\frac{1}{n}\sum_{j=1}^{n}\frac{x_j^2}{n-(\overline{X})^2}}$.

The *Gi** value, also known as the z-score, is a measure of statistical significance. A higher positive value indicates tighter spatial clustering in the hot spot region; a lower negative value indicates tighter spatial clustering in the cold spot region; if the value tends

to 0, the spatial clustering is not significant [45]. Based on the assumption of a normal distribution, the significance level was selected as 5%, corresponding to a critical value of 1.96. This was because what was actually being sought was the area where high values were clustered; the hotspot area for cell set cooperation with a z-score greater than 1.96 is selected.

2.3.3. Identification of the Hierarchical Structure of Nighttime Economic Agglomerations

1. Visualization of the hierarchical structure of nighttime economic agglomerations

When the QPW image was stretched in three dimensions, it became clear that the high-value spots matched the peaks in the topography and that the surface undulation of the image resembled that of a topographic map (Figure 5). Contour lines are employed to depict the surface undulation in topographical studies, and this study drew on this representation to depict the hierarchical distribution of nighttime economic agglomerations.

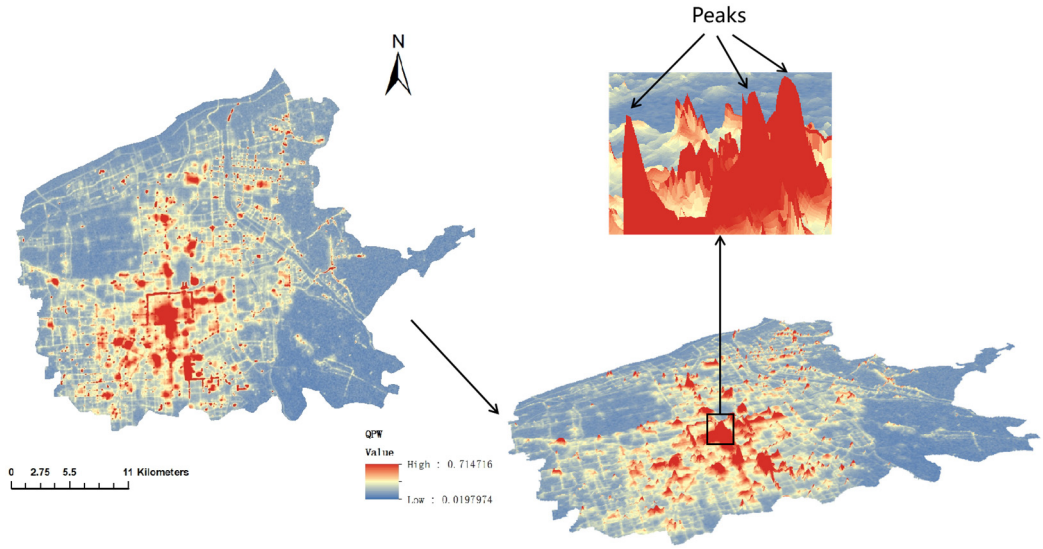


Figure 5. Three-dimensional stretching.

The natural breakpoint approach was used to grade hotspot values identified in the previous step. The hotspot values of the different grades correlated with the crucial values of the various grades of agglomeration ranges. To produce different grades of nighttime economic agglomerations, patches with small sizes were eliminated, and contour lines generated by the hotspot values were converted to an equivalence surface.

2. Functional characteristics of the nighttime economy agglomeration hierarchy

The functional characteristics of the different levels of agglomeration were identified by calculating the proportions of POI categories [46]. If the proportion of a certain POI category was greater than 50%, the functional characteristics of the unit were determined by the POI, and the study unit was judged to be a single functional area. When the proportions of all types of POIs in a unit were less than 50%, the area was considered to be a mixed functional area. The calculation formula is as follows:

$$C_i = \frac{F_i}{\sum_{i=1}^{8} F_i} \times 100\%, \tag{5}$$

where C_i is the proportion in category i of POIs in the study unit and F_i is the frequency density used to count the number of various types of frequency densities in the study unit:

$$F_i = \frac{n_i}{N_i}, \tag{6}$$

where i is a POI category, n_i is the number of POIs in category i within the study unit, and N_i is the total number of POI types in category i.

3. Results

3.1. Xi'an Nighttime Economic Agglomeration Identification Results

On the surface of the QPW composite index image, to generate a sequence of contour lines, the value of each contour is determined by the different hotspot value levels, classified by the natural breakpoint method, and the different values of the contour lines surrounded by the area—that is, different levels of nighttime economic agglomeration—in accordance with the organization of the high-value and low-value nighttime economic agglomeration areas into a scale from I to V to generate the spatial distribution of the map shown in Figure 6.

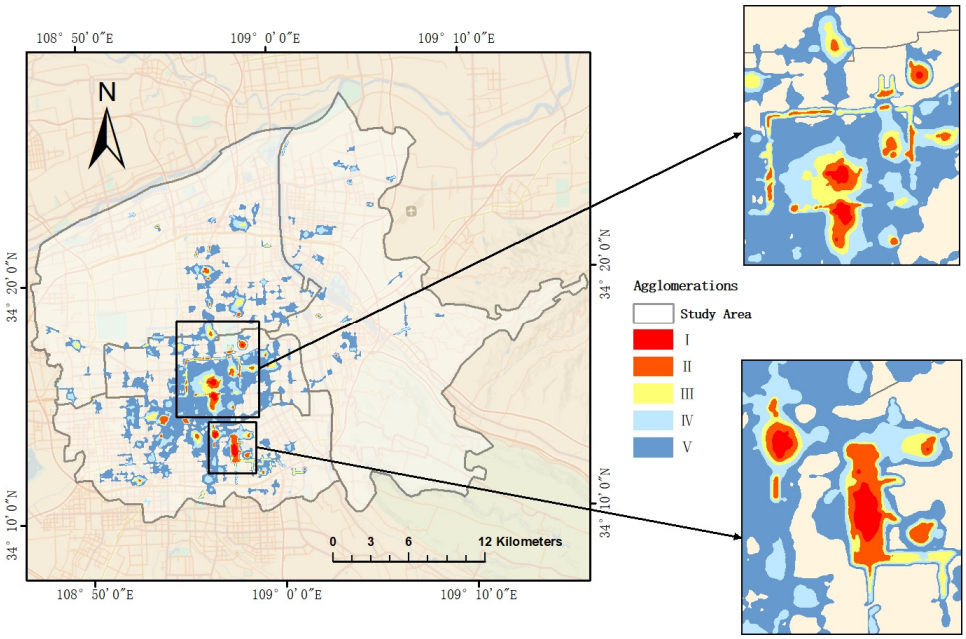


Figure 6. Distribution of nighttime economic agglomerations.

The different levels of agglomeration in the central and southeastern parts of the study area were relatively dense and covered a relatively large area, forming a continuous agglomeration with a complex hierarchical structure. In the northern part of the study area, the agglomerations had a point-like distribution with a smaller area, and low-level agglomerations were dominant. In terms of the distributional characteristics of the different levels, Level I agglomerations were found to be concentrated in the central and southeastern regions of the study area, Level II and III agglomerations were dispersed along the central axis of Xi'an City and its environs, and Level IV and V agglomerations were evenly distributed and spanned a wide range of areas. Areas outside the scope of Level V agglomerations were considered non-agglomerations.

3.2. Validation of Recognition Results

3.2.1. Comparison of Single-Source and Multisource Data Fusion Results

To further illustrate that the multisource data fusion method used in this study is reasonable, experiments were conducted using nighttime lights, POI, and Weibo check-in data, and the results were compared with the recognition results of the QPW composite index. The area around Datang Everbright City and Xi'an Film Studio was selected as an example to show the comparison results in more detail. The neighborhood of Datang Everbright City, one of the most famous and crowded nighttime excursion places in Xi'an, is dominated by squares and pedestrian streets. The area around Xi'an Film Studio contains

large indoor exhibition halls and has numerous night activities, such as night bazaars and open-air concerts. Datang Everbright City and West Studio are represented by Places A and B, respectively, in Figure 7.

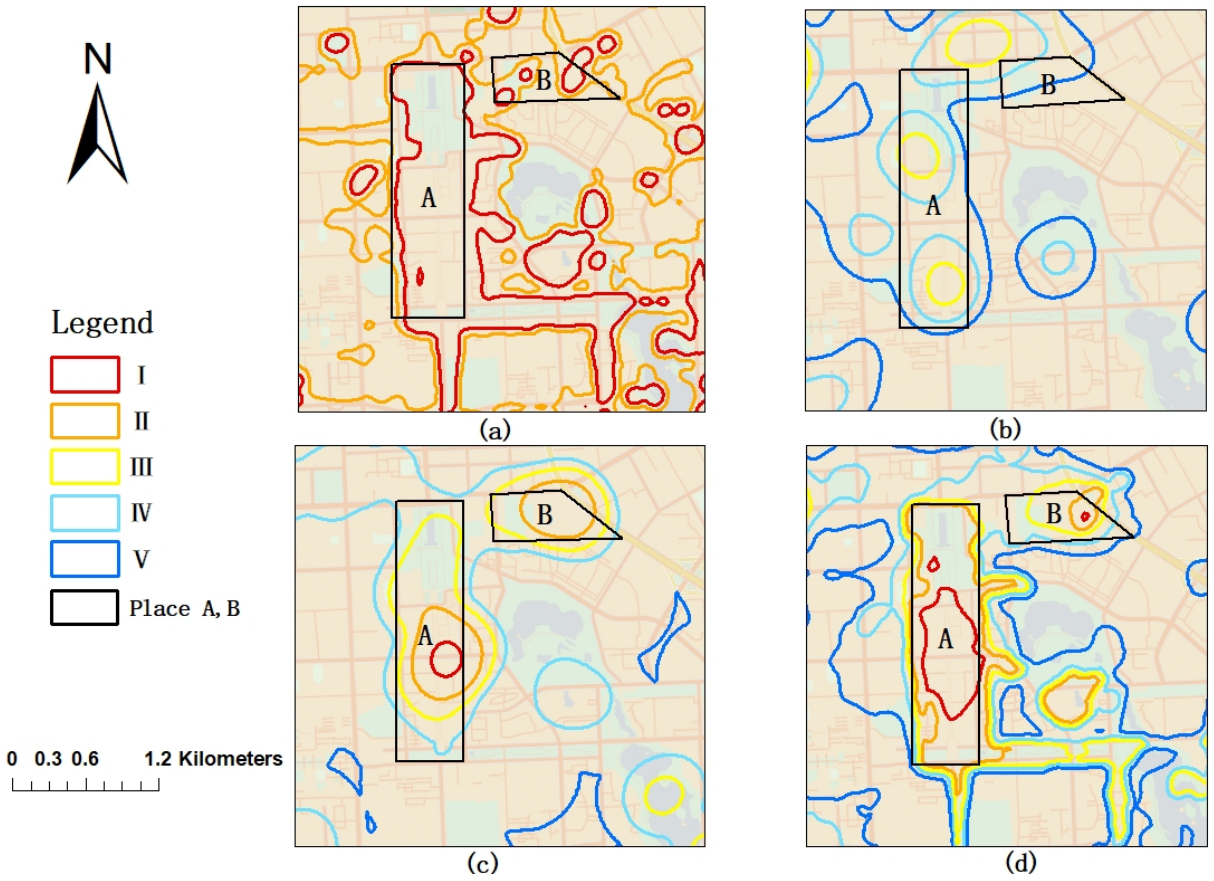


Figure 7. Comparison of single-source and multisource data fusion results: (**a**) experimental results using QMX-1 nighttime light brightness data; (**b**) experimental results using POI data; (**c**) experimental results using Weibo check-in data; (**d**) experimental results using multisource data fusion.

As Figure 7a shows, in the QMX-1 nighttime lighting data, the area was discontinuous, and the agglomerations identified were mostly distributed along the road network, especially at road intersections prone to high-level agglomerations. Place A was better identified and more consistent with its neighborhood pattern, whereas Place B's nighttime activities were mostly indoors or in dim lighting, which suggests that nighttime lighting data do not perform well in identifying this area. Nighttime lighting data were more effective in identifying the strongly illuminated pedestrian street and matching the real neighborhood pattern, but the data were affected by the road lights, and some of the nighttime activities took place in mainly indoor and semi-dark places, which leads to poor identification of the agglomeration area.

Analysis of the POI data did not identify high-level agglomerations in either Place A or Place B, which is inconsistent with reality (Figure 7b). This is because POI data do not include businesses such as bazaars and open-air performances. In addition, because of the lack of scale information, the recognition accuracy is poor for areas containing locations such as large exhibition halls and large theaters.

The Weibo check-in data identified high nighttime economic intensity in both areas because of its close correlation with crowd activity (Figure 7c). However, nighttime economic agglomerations should be a unity of nighttime consumption space and crowd activities. The identification results indicate that there is a large gap between the agglomerations identified using the Weibo check-in data and the actual neighborhood patterns.

To a certain extent, the identification results obtained using the QPW composite index attenuate the defects of the individual data identification processes (Figure 7d); that is, the index retains the characteristics of the urban morphology and the distribution of nighttime service facilities and combines human activities, which can be used to assess the level of nighttime economic agglomerations more comprehensively. The multisource data fusion method adopted in this study was judged to identify scientifically valid nighttime economic agglomerations.

3.2.2. Comparison with Planning Data

To validate the identification results of this study, 34 landmarks in 7 agglomerations within the study area were chosen based on the first 10 nighttime consumption agglomerations released by the Xi'an Municipal Bureau of Commerce.

In Figure 8, the corresponding landmarks are shown as pink circles; all landmarks were included in the nighttime economic agglomerations identified in this study. Table 2 lists the spatial relationships between the specific locations of these landmarks and the nighttime economic agglomerations identified in this study and shows which nighttime consumption agglomeration corresponds to these landmarks. These findings indicate a considerable degree of reliability of the identification results presented in this study.

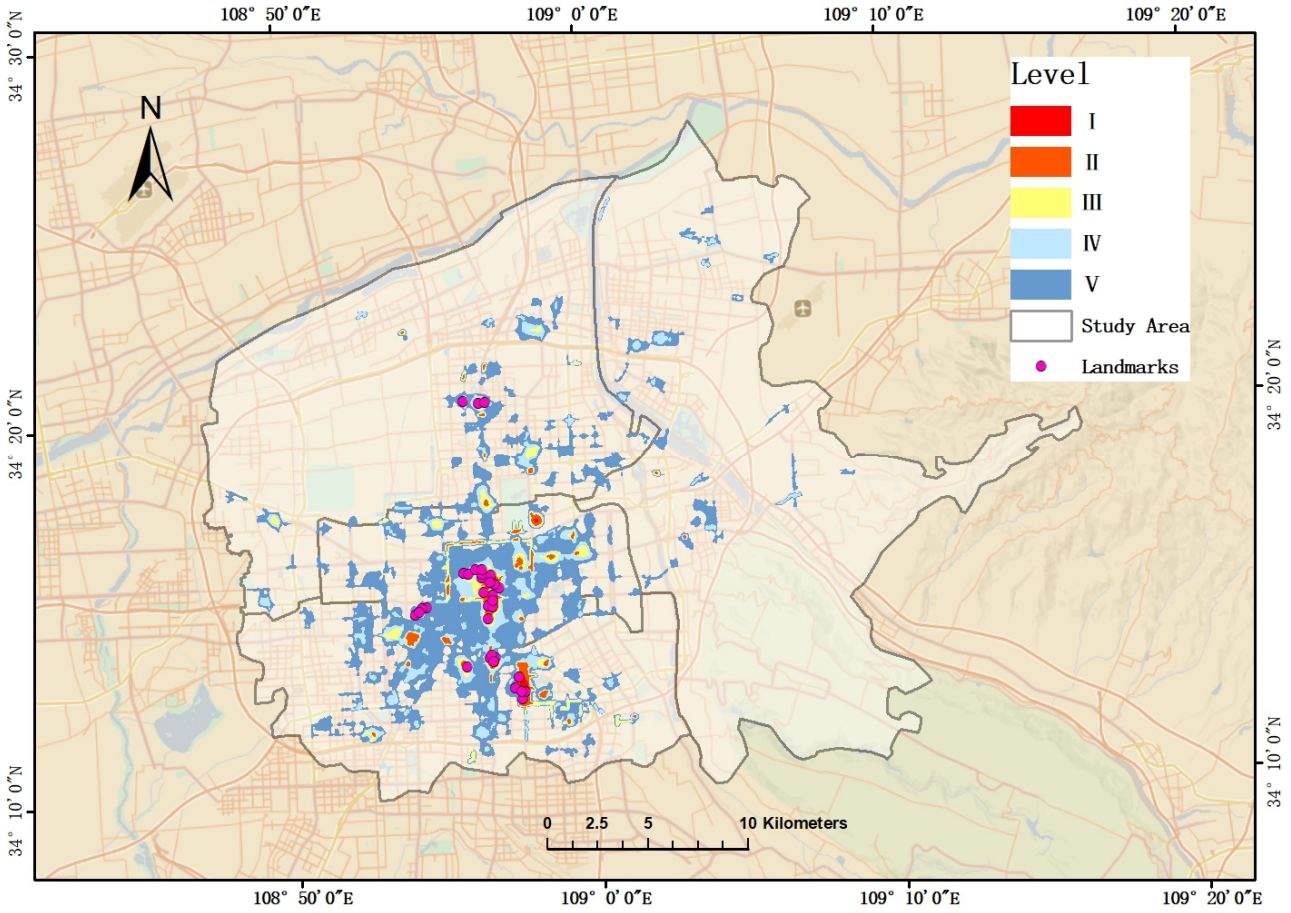
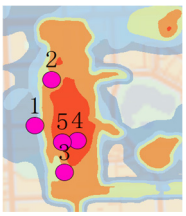
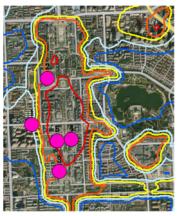
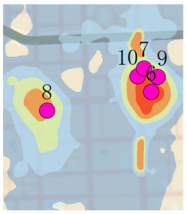
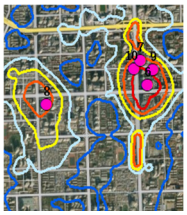
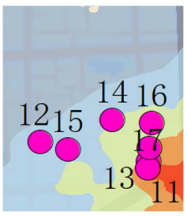
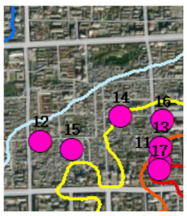
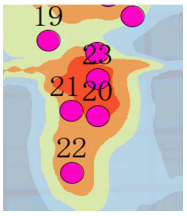
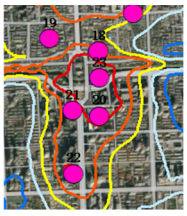
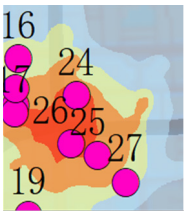
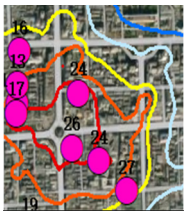
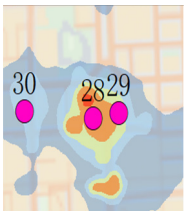
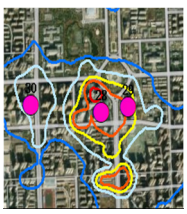
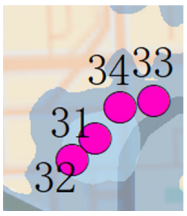
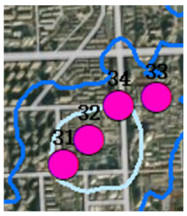


Figure 8. Distribution of nighttime economic agglomerations and landmark locations.

Table 2. Correspondence of nighttime consumption agglomerations and identification results.

Nighttime Consumption Agglomeration	Included Items	Identification Results	Remote Sensing Image
Datang Everbright City	1. Datang Everbright City Commercial Walking Street 2. Xi'an Joy City Mall 3. Qujiang Intime Department Store 4. Xi'an Concert Hall 5. Shaanxi Grand Theater		
Xiaozhai Nighttime Consumption Cluster	6. SAGA International Shopping Center 7. Kinshasa International Shopping Center 8. Momopark Shopping Center 9. Harbour City Shopping Center 10. Xing-Shan Temple West Street		
North Gate Historical and Cultural Block	11. Xiyang Market Street 12. Miaohou Street 13. Muslim Quarter 14. Dapi yard 15. Daxuexi Lane 16. North Courtyard Gate 17. Huejue Lane		
Xi'an South Gate Nighttime Consumption Cluster	18. Shuyuan Gate 19. Defu Lane 20. Shin Kong Place 21. Wangfujing Department Store 22. Zhongmao Plaza 23. Liuyuan Plaza		
Bell Tower Nighttime Consumption Cluster	24. Yisu Theater Cultural District 25. Luoma Pedestrian Street 26. Kaiyuan Mall 27. Dongmutou Street		
Administrative Center Nighttime Consumption Cluster	28. City On Shopping Center 29. Darongcheng Shopping Center 30. Hanshin Shopping Plaza		
Tang West Market in Xi'an	31. Xishicheg Shopping Center 32. Tang West Market Silk Road Style Street 33. Tang West Market International Antique City 34. Tang West Market Museum		

3.3. Hierarchy of Nighttime Economic Agglomerations

3.3.1. Characterization of the Hierarchy

According to the results of the level division of agglomerations, most of the different levels of agglomerations showed a relationship between low-level agglomerations containing high levels; only a few low-level agglomerations exist independently without high-level agglomerations; that is, most of the different levels of agglomerations in the region have obvious hierarchical structures. Regions containing first-level agglomerations have higher and more complex hierarchical structures, which can reflect the distribution patterns of different levels of agglomerations to a certain extent. Therefore, first-level agglomerations were chosen in this study as nodes for use in generating the hierarchical structure map. Figure 9 shows the spatial distribution of the hierarchical structure of agglomerations.

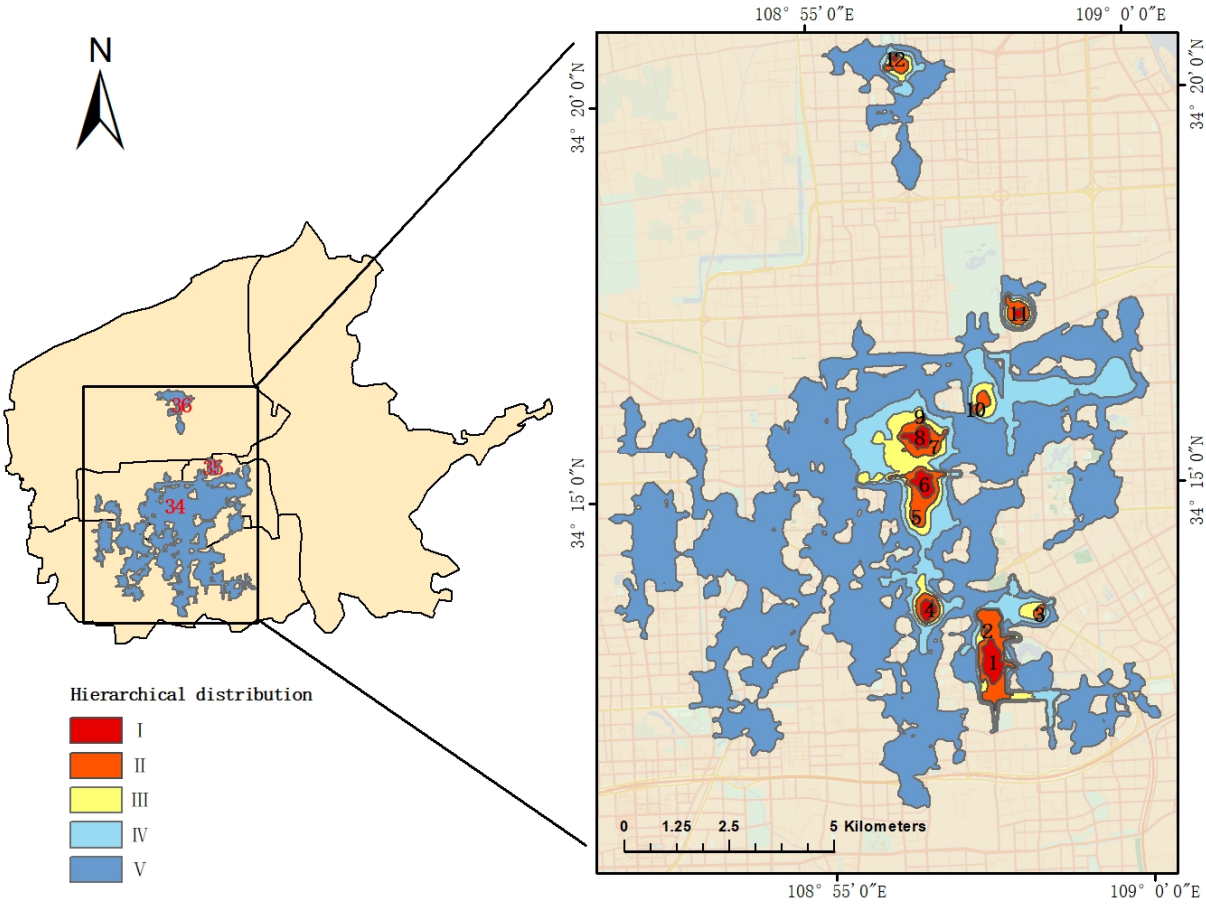


Figure 9. Hierarchical distribution of nighttime economic agglomerations containing primary agglomerations. I–V represent different levels of nighttime economy agglomerations.

The agglomerations were numbered, and the spatial inclusion relationships were organized into the hierarchical structure schematic shown in Figure 10. The hierarchical map was split into three sizable branches that corresponded to agglomerations 34, 35, and 36. Agglomeration 34 had the most complex structure and largest area, with three Level IV agglomerations, five Level III agglomerations, seven Level II agglomerations, and twelve Level I agglomerations. Agglomerations 35 and 36 were geographically far from the other agglomerations, so each level of agglomeration formed a separate hierarchical structure branch. A more centralized spatial distribution of nighttime economic agglomerations is reflected in these features.

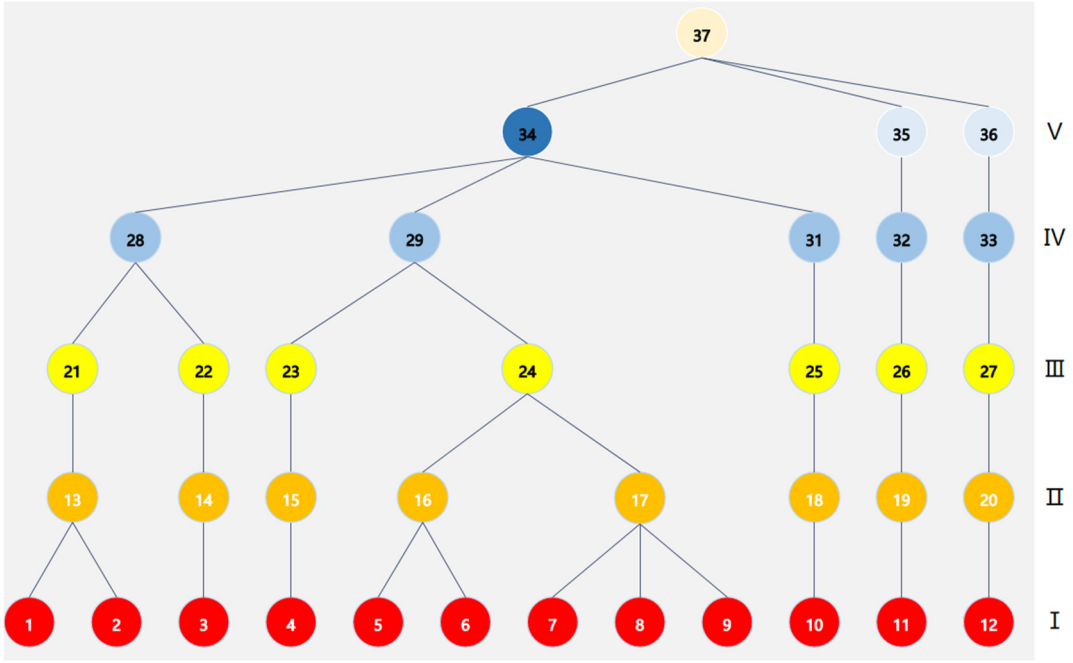


Figure 10. Grade structure diagram. Where different colors represent different levels of nighttime economy agglomerations, and numbers represent agglomeration serial numbers.

In contrast, agglomerations with reasonably discrete distributions typically have a smaller scope and fewer sizes. The secondary agglomerations surrounding Datang Everbright City (No. 13), South Gate (No. 16), and Bell Tower (No. 17) all contain multiple primary agglomerations in terms of local hierarchical relationships, and the remaining five exhibit a one-to-one correspondence. This suggests that the primary agglomerations with the highest heat ratings are typically relatively far apart and tend to display a monocore distribution in the hierarchical map. However, in some areas where the intensity of nighttime activities is comparatively higher, a multicore distribution was also observed. In the third layer, agglomerations 16 and 17 converged at node 24, indicating that they are situated in closely spaced and highly connected locations. The remaining nodes consolidate at the fourth and fifth levels, indicating that agglomerations tend to develop in a contiguous manner and that to generate larger and higher-level agglomerations, links between agglomerations must be strengthened.

3.3.2. Hierarchical Functional Characteristics

Using POIs for functional identification, it is possible to determine that the majority of agglomerations are composed of mixed-functional zones. The two single-functional first-level agglomerations are No. 2 and No. 12, which correspond to the areas within the Administrative Center shopping district and the Datang Everbright City shopping district, respectively. These agglomerations are classified as shopping or catering areas. From the second- to the fifth-level clusters, there are mixed-function zones, indicating that nighttime economic clusters within the six districts of Xi'an have a rich variety of business types and a balanced layout.

Business districts and nighttime economic agglomerations are closely related, and the level structure and size of these spatial agglomerations are influenced by the various market impacts formed by the various business district levels (Figure 11) [47]. The Big Wild Goose Pagoda, Datang Everbright City, Xi'an Film Studio, and other famous large-scale nighttime activity areas are all located in Agglomeration No. 28, which is also home to several large shopping malls and landmark attractions. The area has perfect lighting, unique nighttime landscapes, and many performances and outdoor activity programs that attract visitors and local residents in the evening. These factors combine to form a high-level agglomeration

with a comprehensive hierarchical structure. The area from Xiaozhai to North Street, which is the hub of extensive economic activity and has high population movement, is included in Agglomeration 29. Large retail centers, entertainment venues, and iconic structures are found in the area, and the industry categories exhibit a high degree of maturity. The area contains Agglomerations 16 and 17 within the emergence of a first-level agglomeration area with dual-core and triple-core distributions that primarily consist of shopping, catering, and night excursions. The development of Agglomeration 29 was the most dynamic, exhibiting the largest scale, and the hierarchical structure of its grades was complete. The primary agglomerations located in the northern portion of the study area exhibited a mono-core distribution centered around the administrative center and the Dahua 1935 commercial street area. These agglomerations primarily consist of nighttime dining, shopping, leisure, and entertainment activities. These business modes do not converge with other agglomerations. To improve the scale and level of agglomeration, the diversity of business modes must be improved, and the connections with other agglomerations must be fortified.

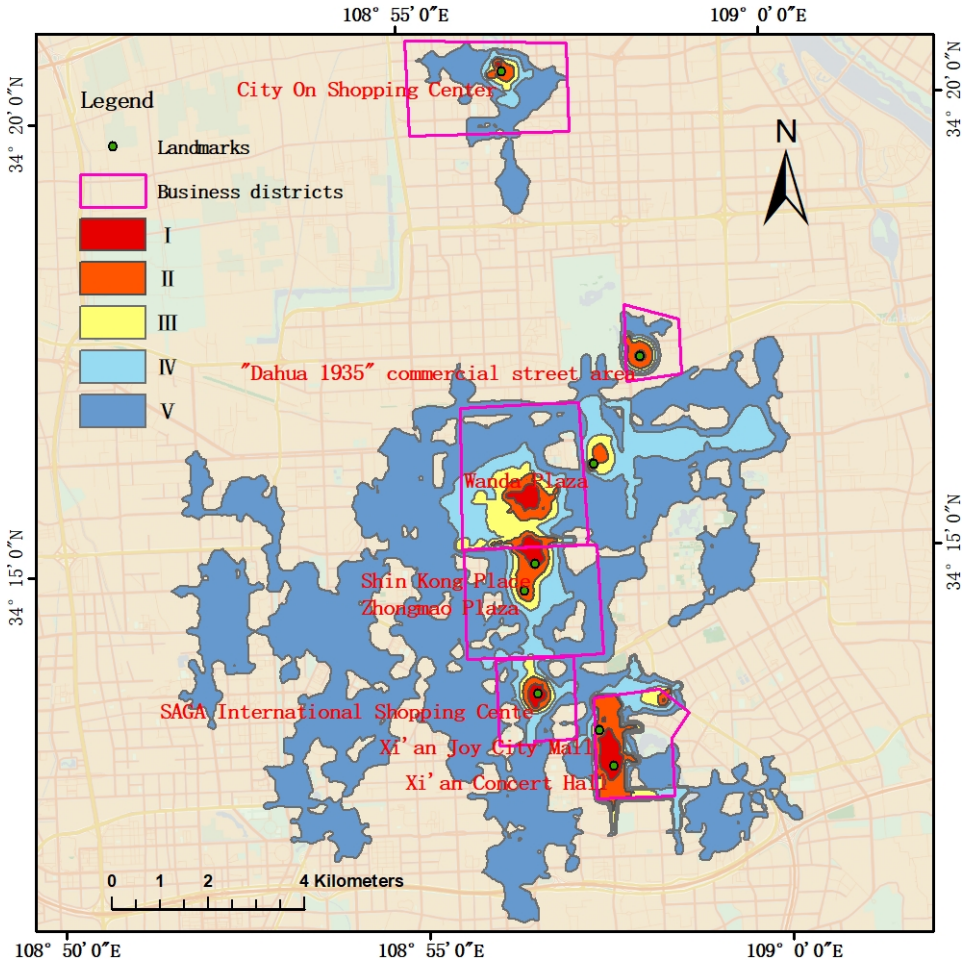


Figure 11. Business districts and typical landmarks.

4. Discussion

4.1. Exploration of the Advantages of Identification Methods

The superiority of the multisource data fusion method used in this study for nighttime economic agglomeration identification is manifested in the following points. (1) The multisource data fusion method used, which combines nighttime lighting data, POI data, and Weibo check-in data, combines two aspects of information about providers in the nighttime economy (facility points and activity spaces) and recipients in the nighttime economy (people) to identify the spatial distribution and structure of nighttime economic

agglomerations. This method overcomes the limitations of using a single source of data in research on identifying agglomerations. (2) This study's definition of the boundaries of a nighttime economic agglomeration is not limited by administrative boundaries, allowing it to reflect the natural form of the agglomeration area better and illustrate the correlation between the level of a nighttime economic agglomeration and its spatial location. (3) This approach provides a basis for investigating the characteristic indices of various levels of nighttime economic agglomerations and for more sophisticated planning and management of these agglomerations by quantitatively identifying their hierarchical structure, which reflects the spatial containment relationship of these levels. Furthermore, the spatial arrangement of various levels of agglomeration can provide some insight into the direction in which agglomerations will develop in the future.

4.2. Policy Recommendations

The identification of nighttime economic agglomerations within Xi'an's six districts reveals that the city's core area contains the majority of the city's high-level agglomerations, whereas the northeastern region is home to many low-level agglomerations scattered throughout the area. High-level agglomerations are parts of a city with highly concentrated features and well-used land. The imbalanced development of the nighttime economy within the six districts of Xi'an is indicated by disparities in the spatial distribution of high- and low-level agglomerations. Consequently, Xi'an should fortify the establishment of nighttime economic agglomerations while capitalizing on circumstances to progressively eradicate disparities in the growth of urban spatial agglomerations and enhance the overall efficacy of urban land utilization.

Additionally, distinct management approaches must be used in a targeted hierarchical manner for varying agglomeration levels. The business environment of the nighttime economy should be optimized in middle- and low-agglomeration areas, management should be strengthened in high-agglomeration areas, and functional agglomeration should be strengthened in peripheral point-like areas. As first- and second-level agglomerations are the busiest, it is important to strengthen them through standardized management and sensible night economy planning. Examples include improving security in relevant areas, concentrating on peripheral traffic issues, and strengthening the design and business planning of night markets and commercial streets. To satisfy local demand for nighttime consumption, it is also necessary to continuously optimize the nighttime economy's supporting infrastructure and increase its size. In addition to developing multifaceted and specialized nighttime economy projects, tertiary and quaternary agglomerations should suitably improve the compactness and connectedness of nighttime economy businesses. To attract more nighttime customers, pertinent supporting factors, including traffic accessibility and lighting brightness, should be maximized. Nighttime economic development should be accelerated in fifth-level agglomerations and peripheral areas to create nighttime economic agglomerations by strengthening functional agglomerations and enhancing supporting infrastructure. Furthermore, various agglomeration levels should enhance economic interoperability. For instance, inner-level agglomerations frequently struggle with housing shortages and traffic jams; thus, corresponding peripheral agglomerations should have suitable supporting infrastructure.

Finally, although the development of the nighttime economy can bring about many positive social impacts, its development should not be unlimited. The single-minded pursuit of growth of the nighttime economy can lead to social problems such as traffic congestion, noise, light pollution, and reduced public safety, which, in turn, lead to a decline in the satisfaction of residents with their daily lives and impedes the sustainable development of the socioeconomic system. Therefore, regardless of the level of agglomeration, the social costs of the nighttime economy should be considered, and achieving and maintaining a balance between economic development and the social environment should be emphasized.

4.3. Shortcomings of the Study and Suggestions for Future Research

The research methodology used in this study also has some limitations. (1) It mainly considers the two aspects of nighttime economy providers and recipients in the process of multisource data selection; however, in measuring the nighttime economy from the perspective of the recipients, the methodology is based on the assumption that areas with a high degree of crowd gathering may have more consumption behaviors. However, there are places in a city, such as sightseeing pedestrian streets and city parks, where crowds gather but do not produce consumption, so more data need to be verified and supplemented. (2) In the process of exploring the attributes of nighttime agglomerations, individual or mixed functional attributes are roughly classified; the attributes of different grades of nighttime agglomerations are not analyzed in greater depth and detail. The specific internal structures of different grades of agglomerations and the possible problems that may exist in different levels of agglomeration should be explored further. Furthermore, the development of different levels of nighttime economic agglomerations is only considered in terms of their spatial distribution; the development of the current status of the agglomerations is not evaluated from different perspectives. Future research should focus on the following aspects. (1) In terms of data, more data should be selected to assess consumption actually generated by the nighttime economy, such as social statistics and social media semantics. (2) The differences in the internal attributes of different levels of agglomerations should be further considered to gain a deeper understanding of the development status of the agglomerations, provide more reasonable and comprehensive support for the development of different agglomerations, and reduce the social problems brought about by the nighttime economy while giving full play to its positive effects to build a more vital and sustainable nighttime economy.

5. Conclusions

In this study, a QPW index was constructed by integrating high-resolution QMX-1 nighttime light data, POI data, and Weibo check-in data. The components of the nighttime economy were comprehensively considered in terms of both providers and receivers by combining multisource data, which makes the research perspective more comprehensive than in previous research. To identify the hierarchical structure of nighttime economic agglomerations and the boundaries of each level, this study used a two-step method to detect hotspots of nighttime economy, which provided support for the accurate identification of the scope of different levels of agglomerations in a quantitative manner and the delineation and analysis of different levels of agglomerations. The following conclusions can be drawn from the results of this study:

(1) The multisource data fusion method employed in this paper was successful in identifying statistically significant hotspots using a two-step method, based on which we achieved the quantitative classification of the hierarchy of nighttime economic agglomerations. This approach provides a new way of thinking about how to identify nighttime economic agglomerations in terms of both data sources and methods. The results of the comparisons conducted show that multisource data fusion overcomes the limitations of using a single type of data. Thirty-four landmarks in seven nighttime economic agglomerations identified by the Xi'an Municipal Bureau of Commerce in the main urban area are in the agglomerations identified in this study. This demonstrates that the identification method used in this study has a certain degree of scientific validity and yields accurate identification results.

(2) This study identified the specific boundaries and spatial distribution patterns of different levels of agglomeration. In the central and southern regions of the study area, the various agglomeration levels collectively created a sizable, consistently distributed, cluster-like area, whereas the northern section was more dispersed. Regarding the distribution of the different agglomeration levels, high-level agglomerations were smaller in number and more centrally distributed than low-level agglomerations, which were more widely scattered.

(3) The identification results obtained in this study show the hierarchy of agglomerations and the inclusionary interactions between them. There are independent hierarchical structures in some northern parts of the study area, which are far from other agglomerations and need to improve the diversity of their business types and strengthen their links with other agglomerations. Different levels of agglomeration were aggregated through nodes in different layers, indicating that agglomerations tend to develop centrally. In terms of functional organization, the nighttime economic agglomeration is dominated by mixed functions, suggesting a more harmonious arrangement of functions within the study region.

Author Contributions: Weijie Wan and Hongfei Chen conceived and designed the study; Weijie Wan implemented the experiments, analyzed the results, and wrote the manuscript; Hongfei Chen, XipingYang, Renda Li, Yuzheng Cui and Yiyang Hu reviewed the manuscript and provided comments. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the National Natural Science Foundation of China (Grant No. 42271468) and the Shaanxi Science and Technology Program (Grant No. 2019ZDLSF07-04).

Data Availability Statement: Data are available on request due to privacy.

Acknowledgments: Thanks to Wuhan University's Qimingxing team for providing the Qimingxing-1 nighttime light image data free of charge. We are grateful for the comments and suggestions provided by the reviewers and editors.

Conflicts of Interest: The data presented in this study are available upon request from the corresponding author. The data are not publicly available because of privacy and morality restrictions.

References

1. Montgomery, J. Cities and the art of cultural planning. *Plan. Pract. Res.* **1990**, *5*, 17–24. [CrossRef]
2. Bianchini, F. Night Cultures, Night Economies. *Plan. Pract. Res.* **1995**, *10*, 121–126. [CrossRef]
3. Mao, Z.G.; Long, Y.N.; Ye, X. Research Prograss on Night-Time Economy. *Econ. Persp* **2020**, *1*, 103–116.
4. Li, M.X.; Tu, W.; Lu, F. Sensing the Nighttime Economy-Housing Imbalance from a Mobile Phone Data Perspective: A Case Study in Shanghai. *Remote Sens.* **2022**, *14*, 21. [CrossRef]
5. Schwanen, T.; van Aalst, I.; Brands, J.; Timan, T. Rhythms of the night: Spatiotemporal inequalities in the nighttime economy. *Environ. Plan. A* **2012**, *44*, 2064–2085. [CrossRef]
6. Valentine, G.; Holloway, S.L.; Jayne, M. Contemporary cultures of abstinence and the nighttime economy: Muslim attitudes towards alcohol and the implications for social cohesion. *Environ. Plan. A* **2010**, *42*, 8–22. [CrossRef]
7. Diaz-Fernandez, S.; Evans, A. Lad culture as a sticky atmosphere: Navigating sexism and misogyny in the UK's student-centred nighttime economy. *Gend. Place Cult.* **2020**, *27*, 744–764. [CrossRef]
8. Tong, H.; Kang, J. Relationships between noise complaints and socio-economic factors in England. *Sust. Cities Soc.* **2021**, *65*, 9. [CrossRef]
9. Fu, H.Y.; Shao, Z.F.; Fu, P.; Cheng, Q.M. The Dynamic Analysis between Urban Nighttime Economy and Urbanization Using the DMSP/OLS Nighttime Light Data in China from 1992 to 2012. *Remote Sens.* **2017**, *9*, 19. [CrossRef]
10. Tang, C.; Xiao, X. Advances and Prospect in Nighttime Tourism Research Home and Abroad. *Human. Geo* **2022**, *37*, 21–29.
11. Wu, F.C.; Wang, Y.F. Urban Nighttime Tourism Consumption Space FromThe Perspective of Scene-A Study Based on the Cultural Scene of Super Wenheyou in Changsha. *Wuhan Univ. J. Phil. Soc. Ed.* **2021**, *74*, 58–70.
12. McArthur, J.; Robin, E.; Smeds, E. Socio-spatial and temporal dimensions of transport equity for London's night time economy. *Transp. Res. Pt. A-Policy Pract.* **2019**, *121*, 433–443. [CrossRef]
13. Cui, Y.Z.; Shi, K.F.; Jiang, L.; Qiu, L.F.; Wu, S.H. Identifying and Evaluating the Nighttime Economy in China Using Multisource Data. *IEEE Geosci. Remote Sens. Lett.* **2021**, *18*, 1906–1910. [CrossRef]
14. Zeng, L.; Liu, T.; Du, P. Research Method of Temporal and Spatial Distribution Pattern of Night-time Economy based on Multi-source Data. *J.Geo-Inf. Sci.* **2022**, *24*, 38–49.
15. Liu, F.; Liu, S.; Zhu, Y. The spatial distribution pattern of nighttime economy carriers in Wuhan. *J. Central China Normal Univ. Nat. Sci. Ed.* **2022**, *56*, 686–694.
16. Wang, L.; Zhong, H.; Xu, Z.; Wang, W. Quantitative Identification and Classification of the Nighttime Economic Agglomeration based on the Luojia-01 NTL Data and Pole-Axis Theory. *J.Geo-Inf. Sci.* **2022**, *24*, 2141–2152.
17. Wang, Y.; Zhao, M. Spatial-Temporal Differentiation and Influencing Mechanism of Night-Time Economic Forms in Tianjin. *Geogr. Geo-inf. Sci.* **2023**, *39*, 134–143.
18. Chen, S. *Exploration and Research on Geo-Informatic Tupu*; The Commercial Press: Beijing, China, 2001.
19. Hu, X.Y.; Wang, Y.D.; Wang, H.; Shi, Y. Hierarchical Structure of the Central Areas of Megacities Based on the Percolation Theory-The Example of Lujiazui, Shanghai. *Sustainability* **2022**, *14*, 20. [CrossRef]

20. Chen, Z.Q.; Yu, B.L.; Song, W.; Liu, H.X.; Wu, Q.S.; Shi, K.F.; Wu, J.P. A New Approach for Detecting Urban Centers and Their Spatial Structure with Nighttime Light Remote Sensing. *IEEE Trans. Geosci. Remote Sens.* **2017**, *55*, 6305–6319. [CrossRef]
21. Zhang, H.; Zhou, X.; Tang, G.; Zhou, L.; Ye, X. Hotspot discovery and its spatial pattern analysis for catering service in cities based on field model in GIS. *Geogr. Res.* **2020**, *39*, 354–369.
22. Xu, X.; Ding, S.; Ding, L. Survey on Density Peaks Clustering Algorithm. *J. Softw.* **2022**, *33*, 1800–1816.
23. Wang, Y.; Xue, D.; Song, Y.; Ma, B. Spatial Structure and Formation Mechanism of Entertainment Industry in Xi'an. *Econ. Geog.* **2022**, *42*, 132–145.
24. Kang, L.; Liu, H.; Cheng, W.; Chen, X.; Li, J. A method of urban facility hot spot recognition considering attribute characteristics. *Bulletin. Surv. Mapp.* **2022**, *1*, 8–14.
25. Zhang, X.Y.; Li, W.W.; Zhang, F.; Liu, R.Y.; Du, Z.H. Identifying Urban Functional Zones Using Public Bicycle Rental Records and Point-of-Interest Data. *ISPRS Int. J. Geo-Inf.* **2018**, *7*, 16. [CrossRef]
26. Hu, Q.; Wang, M.; Li, Q. Urban Hotspot and Commercial Area Exploration with Check-in Data. *Acta Geod. Cart. Sin.* **2014**, *43*, 314–321.
27. Hu, Q.W.; Bai, G.K.; Wang, S.H.; Ai, M.Y. Extraction and monitoring approach of dynamic urban commercial area using check-in data from Weibo. *Sust. Cities Soc.* **2019**, *45*, 508–521. [CrossRef]
28. Pok, S.; Matsushita, B.; Fukushima, T. An easily implemented method to estimate impervious surface area on a large scale from MODIS time-series and improved DMSP-OLS nighttime light data. *ISPRS-J. Photogramm. Remote Sens.* **2017**, *133*, 104–115. [CrossRef]
29. Zheng, Q.M.; Jiang, R.W.; Wang, K.; Huang, L.Y.; Ye, Z.R.; Gan, M.Y.; Ji, B.Y. Monitoring the trajectory of urban nighttime light hotspots using a Gaussian volume model. *Int. J. Appl. Earth Obs. Geoinf.* **2018**, *65*, 24–34. [CrossRef]
30. Tu, Y.; Chen, Z.Q.; Wang, C.X.; Yu, B.L.; Liu, B.J. Quantitative Analysis of Urban Polycentric Interaction Using Nighttime Light Data: A Case Study of Shanghai, China. *IEEE J. Sel. Top. Appl. Earth Observ. Remote Sens.* **2022**, *15*, 1114–1122. [CrossRef]
31. Zhao, N.Z.; Zhang, W.; Liu, Y.; Samson, E.L.; Chen, Y.; Cao, G.F. Improving Nighttime Light Imagery with Location-Based Social Media Data. *IEEE Trans. Geosci. Remote Sens.* **2019**, *57*, 2161–2172. [CrossRef]
32. Sun, M.Q.; Fan, H.C. Detecting and Analyzing Urban Centers Based on the Localized Contour Tree Method Using Taxi Trajectory Data: A Case Study of Shanghai. *ISPRS Int. J. Geo-Inf.* **2021**, *10*, 26. [CrossRef]
33. Huang, B.; Zhao, B.; Song, Y.M. Urban land-use mapping using a deep convolutional neural network with high spatial resolution multispectral remote sensing imagery. *Remote Sens. Environ.* **2018**, *214*, 73–86. [CrossRef]
34. Deng, Y.; Liu, J.P.; Liu, Y.; Luo, A. Detecting Urban Polycentric Structure from POI Data. *ISPRS Int. J. Geo-Inf.* **2019**, *8*, 20. [CrossRef]
35. Shi, F.; Li, X.; Xu, H. Analysis of human activities in nature reserves based on nighttime light remote sensing and microblogging data—Illustrated by the case of national nature reserves in jiangxi province. *Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci.* **2017**, *XLII-2/W7*, 1341–1348. [CrossRef]
36. Rizwan, M.; Wan, W.G.; Cervantes, O.; Gwiazdzinski, L. Using Location-Based Social Media Data to Observe Check-In Behavior and Gender Difference: Bringing Weibo Data into Play. *ISPRS Int. J. Geo-Inf.* **2018**, *7*, 17. [CrossRef]
37. Zhao, N.; Cao, G.; Zhang, W.; Samson, E.L. Tweets or nighttime lights: Comparison for preeminence in estimating socioeconomic factors. *ISPRS-J. Photogramm. Remote Sens.* **2018**, *146*, 1–10. [CrossRef]
38. Devkota, B.; Miyazaki, H.; Witayangkurn, A.; Kim, S.M. Using Volunteered Geographic Information and Nighttime Light Remote Sensing Data to Identify Tourism Areas of Interest. *Sustainability* **2019**, *11*, 29. [CrossRef]
39. Huang, B.; Zhou, Y.L.; Li, Z.G.; Song, Y.M.; Cai, J.X.; Tu, W. Evaluating and characterizing urban vibrancy using spatial big data: Shanghai as a case study. *Env. Plan. B-Urban Anal. CIty Sci.* **2020**, *47*, 1543–1559. [CrossRef]
40. Wang, B.; Loo, B.P.Y.; Liu, J.X.; Lei, Y.Q.; Zhou, L. Urban vibrancy and air pollution: Avoidance behaviour and the built environment. *Int. J. Urban Sci.* **2024**, *20*, 1. [CrossRef]
41. Zhong, Q.; Xiao, R.; Cao, H.; Li, X.; Wu, J. Evaluation of Qimingxing-1 Nighttime Light Image. *Geomatics Inf. Sci. Wuhan Univ.* **2023**, *48*, 1273–1285.
42. Xu, Z.; Gao, X. A novel method for identifying the boundary of urban built-up areas with POI data. *Acta. Geogr. Sin.* **2016**, *71*, 928–939.
43. Xiao, Z.P.; Chai, Y.B.; Zhang, Y. Overseas Life Circle Planning and Practice. *Planners* **2014**, *30*, 89–95.
44. ESRI. *ArcGIS Desktop and Spatial Analyst Extension: Release 10.5*; Environmental Systems Research Institute: Redlands, CA, USA, 2017.
45. Getis, A.; Ord, J.K. The Analysis of Spatial Association by Use of Distance Statistics. *Geo. Anal.* **1992**, *24*, 189–206. [CrossRef]
46. Yu, M.Y.; Li, J.Q.; Lv, Y.Q.; Xing, H.Q.; Wang, H.M. Functional Area Recognition and Use-Intensity Analysis Based on Multi-Source Data: A Case Study of Jinan, China. *ISPRS Int. J. Geo-Inf.* **2021**, *10*, 21. [CrossRef]
47. Zhou, L.L.; Shi, Y.S.; Zheng, J.W. Business Circle Identification and Spatiotemporal Characteristics in the Main Urban Area of Yiwu City Based on POI and Night-Time Light Data. *Remote Sens.* **2021**, *13*, 5153. [CrossRef]

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.