Article

Characterizing Sprawl Development in Urban China: A Perspective from Urban Amenity

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Abstract: Urban sprawl in China presents unique characteristics that differ from those commonly studied in Western contexts, an aspect not fully explored in previous studies. Therefore, taking Wuhan, Hubei as an example and integrating population data, remote sensing data, and POI data, this research offers a perspective on sprawl development in urban China. By incorporating population, urban land use, and urban amenities, this study measures their dynamics to classify urban spaces and employs spatial regression models to identify the characteristics of sprawl development with spatial effects controlled. It further applies geographically weighted regression to examine the underlying spatial heterogeneity. The findings indicate that population growth and urban land expansion do not align perfectly, and further exploration identifies the various trends of sprawl development in urban core and periphery areas. On the other hand, some suburban areas show compact development trends, but the growth of local amenities may be limited due to the historical sprawl development legacies. Regression results reveal specific characteristics of this sprawl development. Key findings include the following: (1) shaped by the triple process of sprawl development of urban renewal, suburbanization, and rural revitalization, Wuhan shows a significant core-periphery structure with the trend of polycentricity; (2) overcrowding in central urban districts is the primary driver of sprawl development; (3) most traditional suburbs in Wuhan have emerged as a consequence of rapid urbanization with a legacy of sprawl development; (4) spatial heterogeneity across urban spaces highlights the necessity for locally tailored approaches to regulating sprawl development.

Keywords: urban sprawl; urban amenity; urban planning; Wuhan; China

1. Introduction

Sprawl development, characterized by low-density, single-use, scattered, and leapfrog development, has emerged as a prominent topic in urban-planning discourse [1]. Scholars have identified a series of concerns about urban sprawl, including urban heat islands, air pollution, residential segregation, and inequality of accessibility [2–4]. As China experiences unprecedented urbanization, Chinese cities have shown a trend of sprawl development despite efforts to curb it [5]. Such sprawl development usually differs from the traditionally recognized urban sprawl in Western literature. First, while suburbanization is an important driver of sprawl development in China and Western countries, it is a completely different process. In China, urban residents' suburbanization process coincides with rural residents' urbanization process, resulting in growth in both suburbs and urban centers [6–8]. In contrast, Western countries usually exhibit a decentralization trend [9–11]. Second, while urban renewal is a typical trend in both Western countries and China, leading to neighborhood changes and gentrification, it is a top-down and state-led process in China with investing in urban villages and infrastructures, while in the Western countries, it is a bottom-up and market-based process [12,13]. In this regard, the consequences of urban renewal on sprawl development may also differ. Moreover, when discussing urban

sprawl in the Chinese context, it is vital to acknowledge the crucial role of the Chinese real estate market. Some studies have highlighted that urban sprawl in China is highly dependent on the structure and behavior of the real estate market [14–19]. Combined with China's land-centered financial system, land revenue may incentivize local governments to seek urban expansion for fiscal revenue continuously, and the development of urban renewal also demands investment that may accelerate the process by the pressure of finance and the population suburbanized relocation [16,20]. Given these circumstances, China's rapid urbanization over the past 30 years has triggered significant concerns about urban sprawl [21,22], and the central government has put forward spatial planning, an integrated approach to managing urban development that seeks to balance social, economic, and environmental objectives [23]. In this context, it is necessary to characterize sprawl development in urban China to understand its process better, identify potential solutions, and prevent further sprawl, which may contribute to the science–policy connection in the policy-making process [24].

Existing literature usually relies on the dynamics, patterns, or morphologies of urban land use, population, and accessibility to measure urban sprawl [25,26]. These studies are usually based on the inter-urban level, that is, to tell whether a metropolitan area is compact or sprawl in general [27,28]. However, urban spaces are never at equilibrium, and planning strategies may need to combine local conditions and development contexts [29]. Indeed, adopting a local perspective when addressing urban sprawl is of great necessity, as it helps tailor solutions to the specific characteristics, challenges, and opportunities of individual cities and regions. It is even more important in urban China as rapid urbanization has left many outcomes from outdated planning and improper development strategies, which may no longer meet the demands of urban residents [30]. Thus, there is an urgent need for a comprehensive approach that provides an understanding of the spatiotemporal dynamics considering local urban contexts.

Moreover, urban spaces are dynamic and ever-changing entities, subject to the influences of population growth, economic development, and shifting social and environmental conditions [31,32]. Monitoring these dynamics is essential for urban planners to devise effective planning strategies [33]. The continuous observation supports the development of adaptive policies and regulations, ensuring that urban spaces remain functional, sustainable, and equitable for all residents. The high dynamics of urban space in China, driven by urbanization, suburbanization, urban renewal, and rural revitalization, necessitate a comprehensive understanding of the development processes [34,35]. However, most studies rely on cross-section data or are focused on long-term effects rather than a dynamic view, which calls for a refreshing scope on sprawl development.

One of the primary concerns of sprawl development is the potential for decreased quality of life and increased urban inequality among residents [36,37]. To address this issue effectively, researchers and planners need to move beyond the traditional view of sprawl as merely an urban form and instead consider it as an urban development process that interacts with various other development factors [38,39]. As a key component of urban development, urbanization quality, and urban well-being, urban amenities may serve as a good indicator of urban inequality [40–43]. While they have also long been linked to urban form, population dynamics, and urban land expansion [44,45], the development of urban amenities is highly related to planning strategies in urban China. However, despite their good intentions and ideologies, these strategies may not always be implemented as intended [46]. Some amenities are bottom-up based. For example, commercial facilities in sprawling areas might not attract private services because of the lack of consumers [47]. Other amenities, such as public services and public transit, may face the problem of imbalanced planning that may not meet local demands [48]. Thus, an understanding of sprawl development from the perspective of urban amenities is urgently needed.

The lack of intra-urban and spatiotemporal studies is partly due to the limitations of urban data [49]. First, despite the high involvement and exploration of remote sensing in urban studies, existing planning decisions, especially in China, still rely mostly on

land surveys or master planning data for land use [50,51]. These approaches are highly reliable but present problems, such as data barriers, high costs, long time intervals, and regional limitations. Therefore, a new trend that applies land cover data extracted from remote sensing imagery is emerging due to its advantages in extensive coverage, low costs, and availability of long-time series data [52,53]. Second, many scholars have widely discussed the quantification of urban amenities, with some studies utilizing POI data to measure urban amenities. However, the lack of stable, multi-year data sources of POI data makes it challenging to conduct a spatiotemporal analysis of urban amenities over a period of time [54]. Finally, the availability of demographic data has been a critical problem, especially in the Chinese context. It is because much of the research involving demographic data is based on the census conducted once every ten years, which cannot meet the needs of real-time analysis considering the rapid population growth [55].

In summary, the existing literature on sprawl development leaves several areas ripe for further exploration. There is a compelling need for research that adopts an intra-urban local perspective, considering the unique challenges and opportunities presented by rapid urbanization, as well as changing socio-economic and environmental factors [56]. This approach is crucial for formulating planning strategies tailored to individual cities' specific conditions and contexts. Furthermore, studies capturing the spatiotemporal dynamics of urban spaces can help inform the development of adaptive policies and regulations, fostering urban areas that are functional, sustainable, and equitable [57]. Finally, incorporating urban amenities into sprawl development studies can provide valuable insights into urban inequality and guide planners in understanding the potential impacts of planning strategies on urban residents' quality of life and well-being [58,59].

To address these gaps in the literature, this paper makes several key academic contributions. First, it offers an in-depth examination of sprawl development with Chinese characteristics from an intra-urban perspective, focusing on Wuhan, Hubei. This approach allows for a more nuanced understanding of how rapid urbanization shapes sprawl development in specific urban contexts. Second, this study employs a spatiotemporal approach to capture the dynamic nature of urban spaces in Wuhan. It will enrich the current understanding of how urban spaces evolve. Third, by integrating the perspective of urban amenities, this research offers a fresh angle on the implications of sprawl development for urban inequality and residents' quality of life.

Drawing upon these research backgrounds, this paper aims to contribute to the understanding of sprawl development in urban China, taking Wuhan, Hubei as an example. Relying on remote sensing data and urban open data, this study can provide a fresh and up-to-date perspective on the dynamics of urban spaces. By focusing on the intra-urban and spatiotemporal dimensions of sprawl development, this paper sheds light on the specific local characteristics, challenges, and opportunities arising from the rapid urbanization process in Wuhan. Furthermore, this research integrates the perspective of urban amenities to explore the implications of sprawl development on urban inequality and quality of life for the city's residents. Through the analyses in this research, this study aims to answer the following questions: What are the development trends in Wuhan? How should the urban spaces in Wuhan in terms of urban form be characterized? How do urban amenities relate to sprawl development in the city? By addressing these questions, this paper hopes to provide valuable insights into spatial planning to tackle the challenges of urban sprawl and promote sustainable urban development in China.

2. Materials

2.1. Study Area

Figure 1 illustrates Wuhan, a megacity in China and the capital of Hubei Province. The city center of Wuhan is characterized by the presence of the Yangtze River and its largest tributary, the Han River, which create a distinctive pattern referred to as the "two rivers and three towns". In recent years, Wuhan has experienced significant development, evidenced by its growing GDP from CNY 1090.56 billion in 2015 to CNY 1771.68 billion in 2021, a rise

in population from 10.61 million people in 2015 to 13.65 million people in 2021 [60,61], and tremendous urban expansion. However, empirical studies have also expressed concerns about sprawl development and its impact on the environment and urban equity [62,63]. These issues are significant to this study and will be further investigated.
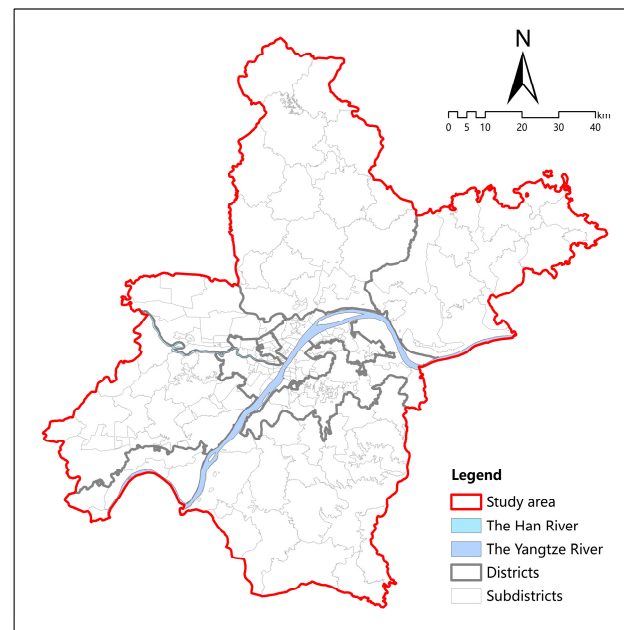

Figure 1. Study Area.

This study centers its analysis on the subdistrict level, referred to as "Jiedao" in China. Wuhan, with its 161 subdistricts, follows the standard administrative division framework commonly employed in China and commonly used in previous research.

2.2. Data Source

This study uses Landsat 8 and Landsat 9 satellite remote sensing imagery to extract urban land use. The Landsat 8 images were acquired in summer 2015, 2017, and 2019 to eliminate the seasonal influence. The datasets for the year 2021 were acquired by the Landsat 9 satellite, which is similar to Landsat 8 and consists of two sensors called OLS-2 and TIRS-2. By applying Landsat 9 satellite, we are able to obtain the most up-to-date information on land use, which has been widely applied in peer studies [64,65].

Point of interest (POI) is used as the index to measure the urban amenities [66], which were obtained from the AutoNavi Open Platform (https://lbs.amap.com/, accessed on 1 May 2023). Since urban services often lag behind urban expansion, this study selected POI data from 2016, 2018, 2020, and 2022, corresponding to remote sensing image data. The POI data includes sixteen types, covering various fields, such as production, living, and ecology. Some research suggests that different types of urban amenities impact urban life and production differently. Therefore, in this research, the POI data were classified into four categories based on the urban amenity classification by Glaeser et al. [67]: service and consumer goods (SCG), public service (PS), transportation service (TS), and tourist attraction (TA). The classification of POI is shown in Table 1.

Population data were derived from the LandScan population dataset (https://landscan.ornl.gov/, accessed on 1 May 2023). This dataset is widely regarded as one of the best for analyzing vital global statistics at approximately 1 km (30" × 30") grid resolution [68]. In addition, the LandScan raster dataset contains population density information, and the total population of the street was processed into SHP files of Wuhan streets.

Table 1. The classification of POI.

Category	Contents	Descriptions
Service and Consumer Goods	Food and Beverages Shopping Motor Service Private Financial Service Daily Life Service Sports and Recreation Accommodation Services	Facilities for consumption, such as restaurants
Public Service	Public Financial Service Science and Educational Services Medical Service Government Organization and Social Group	Facilities for public service, such as hospitals
Transportation Service	Transportation Service	Traffic facilities, such as motor stations
Tourist Attraction	Tourist Attraction	Famous sight spots

2.3. Methods

2.3.1. Land Use Identification

This study classified four primary urban land uses: water, vegetation, built-up areas, and bare areas. Water mainly includes lakes, rivers, and reservoirs; vegetation mainly comprises forests and grasslands covered by plants. This study utilized the Modified Normalized Difference Water Index (MNDWI) to capture water bodies [69], the Normalized Difference Vegetation Index (NDVI) to extract vegetation cover [70], the Normalized Difference Built-Up Index (NDBI) to identify built-up areas [71], and regards other land uses as bare areas as they are not the focus of this study.

2.3.2. Modeling Characteristics of Urban Sprawl

This study employed regression models to identify the characteristics of sprawl development in Wuhan. The dependent variable is the degree of sprawl development. Measured by the ratio of urban expansion rate to population change of each subdistrict (Jiedao), it is regarded as a widely applied indicator for measuring sprawl development [72]. A value greater than 1 means a sprawl development trend, and a value equal to or less than 1 represents a compact or balanced development trend.

According to the preliminary examination, the dependent variable shows a strong spatial autocorrelation, indicating the underlying spatial heterogeneity of development patterns. Consequently, two models were employed to identify the characteristics of urban sprawl. The first is the spatial filtering model (SFM), a widely used regression model that adjusts for spatial dependencies among variables [73]. The second one is the geographically weighted regression (GWR) model, which provides more details in heterogeneous urban spaces and a deeper understanding of the local patterns [74]. The independent variables are listed in Table 2 to estimate coefficients for each location, allowing for a spatially varying regression that accounts for spatial non-stationarity. It should be noted that these models aim to reveal the characteristics of urban development patterns in Wuhan but do not represent causality relationships.

Table 2. Description of the variables in the model.

Variable Name	Category	Description
Popden	Population	The population density in 2015
Rscg	Urban Amenity	Rate of change in service and consumer goods amenities
Rps		Rate of change in public service amenities
Rts		Rate of change in traffic service amenities
Rta		Rate of change in scenic spots amenities

3. Development Patterns in Wuhan

3.1. Demographic Development

This research collected and counted population data for each subdistrict in Wuhan. According to the statistics, the population of Wuhan has shown an increasing trend from 2015 to 2021. During this period, it grew from 10.61 million to 13.65 million, representing a growth rate of 28.67%. This paper compared the rate of change in the local populations of subdistricts with the average rate of change in the population in Wuhan. Subdistricts with rates of change equal to or less than the average rate of change in Wuhan were categorized as having non-significant population development. It implies that the populations in these subdistricts are growing slower than or equal to the average population growth in Wuhan. Those subdistricts with rates greater than the average rate in Wuhan were defined as having significant population growth. The results of demographic change in Wuhan are shown in Figure 2. The subdistricts with non-significant population growth exhibit distinct spatial distribution characteristics. Some are situated in the city's core, such as the Jiyuqiao subdistrict, Liangdaojie subdistrict, and Shouyilu subdistrict, considered Wuhan's oldest and most affluent districts. Due to the urban renewal or gentrification processes, these subdistricts may undergo slow population growth or decline. On the other hand, other subdistricts with non-significant population growth are mainly located in the periphery of Wuhan, primarily in rural areas. Therefore, it could be attributed to the urbanization of rural populations. Those subdistricts with significant population growth in Wuhan are mainly distributed in the city edge and suburbs, which keep the population attraction after undergoing urbanization, such as the Hongshan subdistrict, Baishazhou subdistrict, and Yongfengjie subdistrict. Therefore, in terms of the spatial pattern of population growth, Wuhan exhibits a polycentric trend with a core-periphery structure.
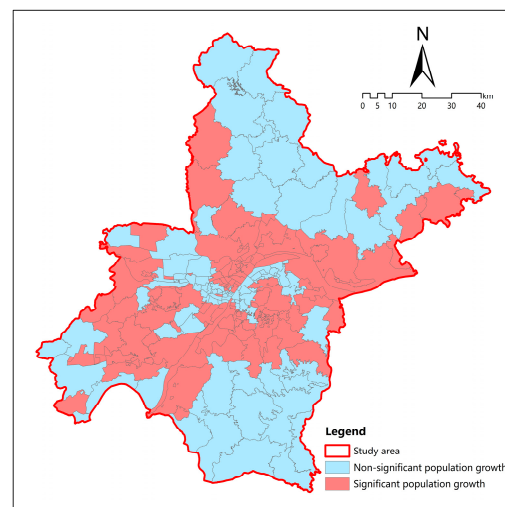

Figure 2. Demographic change from 2015 to 2021.

3.2. Patterns of Urban Land Use Expansion

The dynamics of urban built-up areas are illustrated in Figure 3. The expansion of urban built-up areas in Wuhan can be classified into three modes. In the northern part of the city, particularly in the Huangpi and Xinzhou districts, the growth of built-up areas is characterized by a uniform and scattered distribution, indicating a slower urbanization process, which could be due to limited land availability and stricter land use regulations under the background of ecological protection. On the other hand, the southern peripheries, such as Caidian and Jiangxia districts, show a strong concentration effect in urban expansion, forming new urban subcenters. Finally, the urban expansion shows a clear core-periphery structure, exhibiting a spatial pattern that radiates from the center to the periphery. Overall, the growth of built-up areas in Wuhan displays distinct regional

disparities with the characteristics of north-south division, polycentric development, and core-periphery structure.
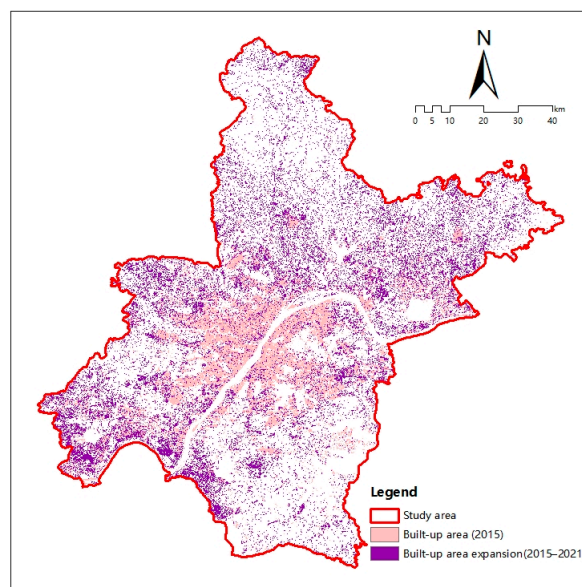

Figure 3. Urban built-up area expansion from 2015 to 2021.

3.3. Sprawl or Compact? Development Trends Based on Population and Land Use

In this paper, the degree of sprawl development was measured by an index based on the rate of change in built-up areas to the change in population. Subdistricts with rates of change equal to or less than 1 were considered as having a compact or balanced trend. Therefore, subdistricts with rates greater than 1 were identified as having a sprawl trend, implying that the population growth does not match local urban expansion. Figure 4 shows the spatial patterns of development trends. The subdistricts with a sprawl trend are mainly located in suburban districts and rural areas, characterized by being relatively underdeveloped with great potential in the context of urbanization and rural revitalization. A few are located in the central urban district, probably due to the urban renewal project that local people might relocate to the suburbs. In the meantime, some subdistricts exhibiting a compact or balanced trend are situated in Wuhan's central region, which is widely regarded as the city's most prosperous and affluent core area. Within these subdistricts, built-up areas are generally saturated; in certain instances, they even experience declines. This phenomenon may be attributed to the reconstruction of old urban areas in the context of urban renewal. Further, suburban subdistricts also exhibit a compact or balanced trend. It may be because the built-up areas in these subdistricts have already undergone significant development during the past few decades of urbanization. While these areas remain attractive for both migration from central urban areas and influx from rural areas, the recent growth of the built-up areas is relatively low.

By comparing the development patterns of demography, urban expansion, and development patterns, it can be concluded that the expansion of urban built-up areas does not always align with population growth. In many cases, there is a mismatch between population growth and built-up area expansion, which may result in differences in urban sprawl patterns and unexpected urban development. Based on the expansion of the built-up area in Wuhan and the population growth, some initial observations can be made regarding the characteristics of Wuhan's urban space. However, changes in population and built-up areas may not fully capture the aspects of local urban life. Thus, to conduct a more comprehensive study and understand the underlying causes of different spatial patterns in Wuhan, it would be beneficial to introduce the concept of urban amenities and classify the subdistricts accordingly. Based on this classification, we can comprehensively understand sprawl development and its characteristics in Wuhan.
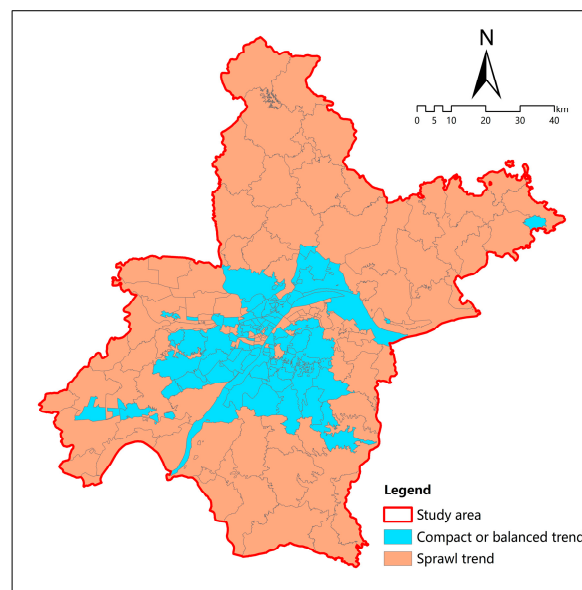
Figure 4. Development trend (2015 to 2021).

3.4. Development Trends Based on Population, Land Use, and Urban Amenity in Wuhan

As a measure of urban service quality, urban amenity is a crucial factor influencing urban development. By monitoring changes in urban amenities, an assessment can be made regarding whether the construction of urban services is keeping pace with population and built-up area development, which can provide a more comprehensive understanding of urban sprawl. Therefore, in addition to land use and population data, this research has incorporated urban amenities as an indicator to classify urban subdistricts. We compare the change rates of population and urban amenities and further identify if the urban services per capita have a higher growth rate than the city average. We then combine these results with the dynamics of sprawl development and population to classify the urban spaces as shown in Table 3, and the classification results are illustrated in Figure 5.

Table 3. Classification of the urban area.

Type	Degree of Sprawl Development	Urban Service Change	Demographic Change
Urban Renewal with Compact Development	≤ 1	<1	≤ 1
Sprawling Area with Compact Development	≤ 1	<1	>1
Gentrification with Compact Development	≤ 1	≥ 1	≤ 1
Balanced Growth with Compact Development	≤ 1	≥ 1	>1
Urban Renewal with Sprawl Development	>1	<1	≤ 1
Imbalanced Growth with Sprawl Development	>1	<1	>1
Rural Revitalization	>1	≥ 1	≤ 1
High-Speed Urbanization of Urban Edge	>1	≥ 1	>1

The subdistricts in Wuhan were divided into eight types based on the degree of sprawl development, urban amenity change, and demographic change. Urban renewal with compact development subdistricts (Type 1), such as the Jiyuqiaojie subdistrict, Liangdaojie subdistrict, and Shouyilu subdistrict, are mainly located in the core city of Wuhan and are considered the most developed areas in Wuhan. As urban development has progressed, these subdistricts have gradually become the old town of Wuhan. The available space for built-up areas is limited, and the slow growth or even decrease of population and urban amenities in these areas may be due to the renewal of the old city. The compact development pattern in Wuhan's core urban area results from urban renewal and development.

In addition to the areas undergoing urban renewal, despite decades of urbanization, the sprawling area with compact development subdistricts (Type 2), located in the outer city core and suburbs of Wuhan, continue to attract populations. However, the growth of built-up areas and population has slowed. These areas have undergone rapid urbanization and are still attractive to residents but might be traditionally regarded as sprawl areas because their planning might not fully meet residents' demand, which could be reflected in the insufficient growth of urban amenities compared to the population growth.
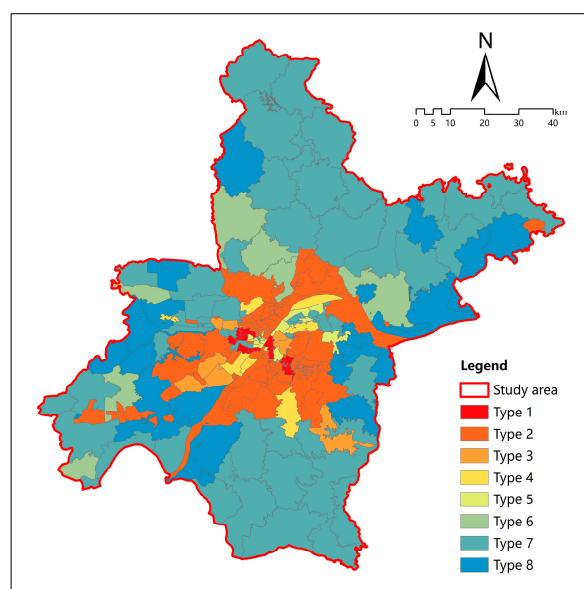

Figure 5. Subdistrict classification for development pattern: Type 1: urban renewal with compact development; Type 2: sprawling area with compact development; Type 3: gentrification with compact development; Type 4: balanced growth with compact development; Type 5: urban renewal with sprawl development; Type 6: imbalanced growth with sprawl development; Type 7: rural revitalization; type 8: high-speed urbanization of urban edge.

The gentrification with compact development subdistricts (Type 3) are also mainly located in the central city and suburban part of Wuhan. With compact development patterns in these subdistricts, higher-income residents tend to move in, replacing lower-income residents. This process of gentrification is often accompanied by an increase in urban amenities in Wuhan. For instance, after years of development, the Zhuankou subdistrict has become a significant economic development zone in Wuhan. The area's transformation resulted in the displacement of farmers and the establishment of enterprises and factories. In summary, subdistricts with a compact development trend generally have a strong foundation for development and attractiveness and are considered the core areas of Wuhan.

Sprawl development is one of the main characteristics of the exurban part and the edge of Wuhan. The imbalanced growth with sprawl development subdistricts (Type 6) is the focus of our discussion and criticism. However, these subdistricts are relatively fewer and are dispersed across the southern edge and northern suburbs of Wuhan compared to other types of subdistricts. There is high growth in urban built-up areas and population in these subdistricts while lacking a matching urban amenity growth. This mismatch can be considered as the excessive urban sprawl in the process of urban development that may result in a decline in quality of life and social inequality. Thus, the government can employ land use policies, urban planning, and other measures to limit the scope and pace of urban expansion, thereby preventing excessive urban development and sprawl.

Most rural revitalization subdistricts (Type 7) and high-speed urbanization of urban edge subdistricts (Type 8) are in urban peripheries. In the context of rural revitalization, many rural areas have undergone rapid development, resulting in an expansion of built-up

areas and the enhancement of urban amenities. However, the phenomenon of population outflow from rural areas is prevalent in major cities across China. Therefore, declines or low population growth in these subdistricts are expected. Accordingly, the subdistricts that can maintain population attraction with the rapid growth of urban land and urban amenity are defined as high-speed urbanization of urban edge subdistricts, which are spatially closer to the urban core and are considered the areas with the most development potential.

However, urban renewal with sprawl development subdistricts (Type 5) is an exception to Wuhan's urban development, concentrated in the urban core, especially the Jianghan, Qiaokou, and Qingshan districts. This type of urban subdistrict can be classified into two patterns. For example, subdistricts such as the Minzu, Minquan, and Hualou in Jianghan and Qiaokou districts exhibit low growth in population and urban amenities despite their sprawl development. It is due to the urban renewal process, an inevitable aspect of central urban region development, and should be encouraged to improve the urban environment. On the other hand, the urban renewal with sprawl development subdistricts in the south of the Yangtze River, such as the Honggang subdistrict and Qingshanzhen subdistrict, are mainly industrial areas built in the early years. Thus, these subdistricts' development patterns may be attributed to the transformation of Wuhan's industrial suburbs in recent years, requiring policymakers to pay more attention to high-quality development and space utilization in urban planning.

4. Characteristics of Urban Sprawl in Wuhan

4.1. Regression Results of the Spatial Filtering Regression

The regression results of the spatial filtering regression are presented in Table 4. From the results, several critical characteristics of sprawl development city-wide in Wuhan can be identified. First, population density as of 2015 is positively related to sprawl development. Such a positive relationship implies that the core driving force of sprawl trends in Wuhan is the overcrowded central urban districts. People may try to move out of the overcrowded areas, showing declining populations in urban core areas and presenting a sprawl trend. This outmigration may move into the suburbs, extending local urbanization pressures. Second, service and consumer goods are positively linked to sprawl development, implying the two undergoing processes. One is the unfulfilled amenity development in the current compact developing regions, mainly the suburbs. Another is that the private services in the urban periphery might be large commercial squares without enough housing mixture to ensure attractiveness, contributing to sprawl development. On the other hand, public service is negatively linked to sprawl development, reflecting local government's efforts in controlling sprawl development by implementing public services and indicating spatial inequality concerns.

Table 4. Regression Results of SFR.

Variable Name	Category	Coefficient
Popden	Population	0.004 ***
Rscg		0.76 ***
Rps	Urban Amenity	−0.51
Rts		0.05 *
Rta		0.22

Significance: *** < 0.001; * < 0.1. The coefficients of the spatial eigenvector vectors are significant but not listed.

These results show the recent trends of urban development in Wuhan. However, they are not able to identify local characteristics. Thus, the GWR model is applied to uncover these local contexts.

4.2. Regression Results of the GWR Model

Figure 6 presents the spatial distribution of local coefficients in the GWR models. The deeper shades of red indicate a higher intensity of positive correlation, while deeper shades of blue represent a higher negative correlation. This analysis provides valuable insights into the spatial characteristics of the relationships between variables in the models. Considering spatial heterogeneity enables us to explore differences among different regions based on the overall relationship between variables.
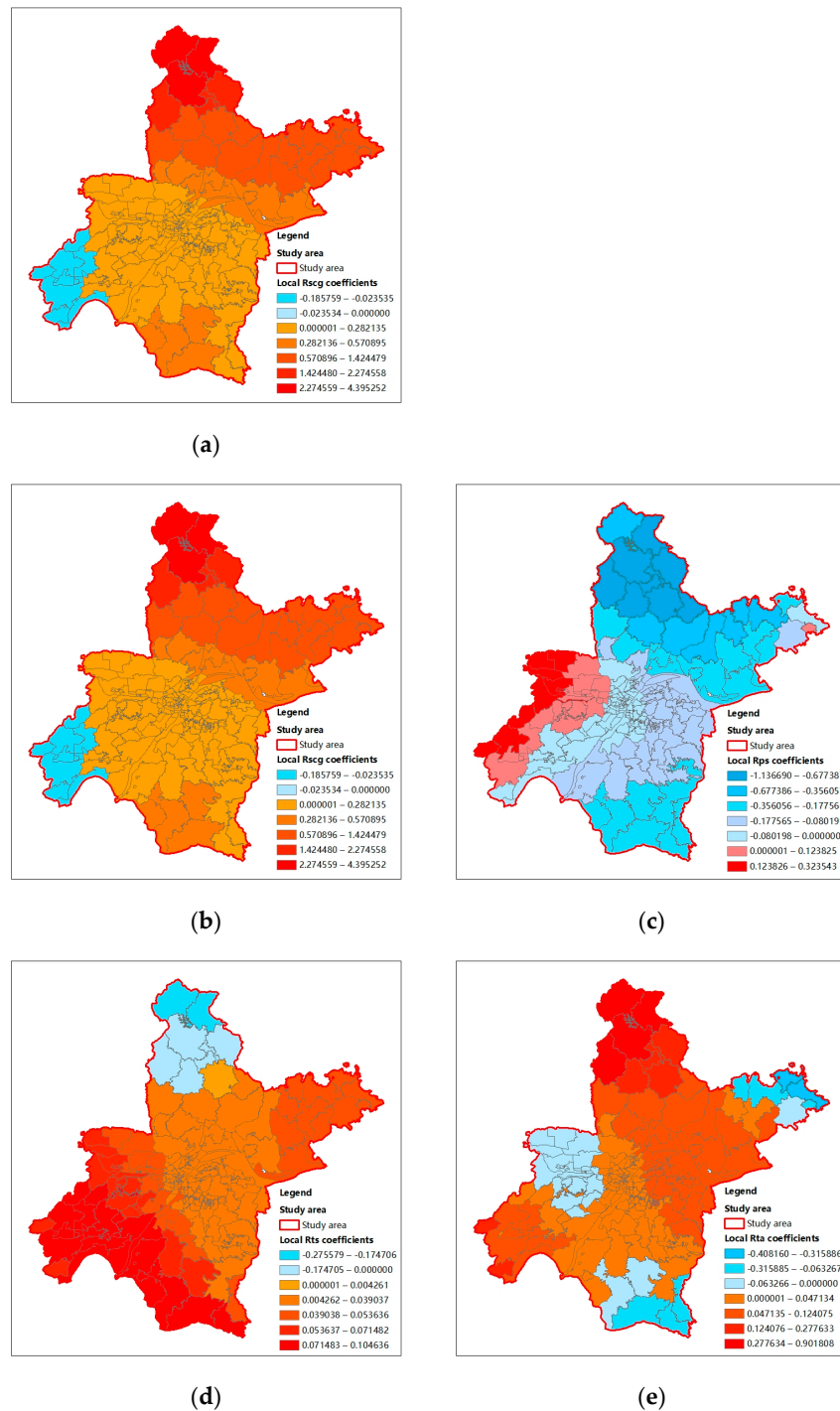

(**a**)

(**b**)

(**c**)

(**d**)

(**e**)

Figure 6. Spatial characteristics of estimated coefficients of variables with GWR models: (**a**) local Popden coefficients; (**b**) local Rscg coefficients; (**c**) local Rps coefficients; (**d**) local Rts coefficients; (**e**) local Rta coefficients.

According to the findings presented in Figure 6a, it is evident that population density (Popden) has a positive impact on Wuhan's urban sprawl in most subdistricts. It might be because high population density drives urban sprawl, as demand for additional services and living space fuels the expansion of built-up areas and triggers outmigration. However, the southwestern and southeastern parts of the city are exceptions, as population density hurts the degree of urban sprawl. It could be because these subdistricts are considered critical ecological spaces according to the master plan for Wuhan's territorial space, severely limiting the development of built-up areas. Moreover, these areas are usually identified as rural hollowing areas, which should be a concern for rural development [75].

Similarly, as shown in Figure 6b, the change rate of service and consumer goods (Rscg) is positively associated with the degree of urban sprawl in most of the subdistricts in Wuhan, except for the southwestern part of the city. It reflects the concern that those "compact developing" areas lack private service development due to the previous planning legacies, which, unsurprisingly, are located in the central urban district. These results also indicate that private services should be carefully planned in northern Wuhan.

On the other hand, the change rate of public service (Rps) is negatively associated with the degree of urban sprawl in most subdistricts. Such a relationship reflects that the government aims to invest in public service facilities to improve local life quality and control urban sprawl [76]. By observing the distribution of local Rps coefficients, local Rps coefficients decrease from the southwestern core city to the periphery. It suggests that public services have a better controlling effect on urban sprawl in the urban periphery but a relatively weaker effect in the central urban area. It also raises the concern that most public services, especially high-quality ones, are concentrated in urban centers, resulting in a lack of public service in non-central areas. However, in the southwest edge of Wuhan, Rps has a positive effect on the degree of urban sprawl, which is probably due to the limitation of ecological space.

Figure 6d shows that the change rate of transportation service positively relates to the degree of urban sprawl in most subdistricts, excluding the subdistricts surrounding Mulan Mountain, an ecological space in Wuhan. This pattern shows the government's efforts to connect urban built-up areas by building transportation services. However, the local Rts coefficients decrease from the southern part of Wuhan towards the north. It may be attributed to urban sprawl creating more built-up centers in the south of Wuhan, whereas the built-up areas in the north are more scattered.

As shown in Figure 6e, the change rate of tourist attraction (Rta) is positively associated with the degree of urban sprawl in most spaces in Wuhan. It suggests that in the process of urban sprawl, cities tend to promote the development of urban landscapes. However, there is a negative relationship between Rta and the degree of urban sprawl in three regions: the southeastern part of the city, mainly in the Mubu Mountain ecological space; the northeastern part of the city, also considered an important Mountain ecological region; and the west of Wuhan. It is because the development of ecological space is strictly regulated, with a focus on preserving its natural landscape. On the other hand, the western part of the city follows intensive development surrounding cities, promoting the urbanization of certain subdistricts.

5. Discussion

According to the development patterns in Wuhan, there is a finding that Wuhan follows a significant core-periphery development structure with the trend of polycentricity. The urban development is of the great north-south division, as northern Wuhan has more scattered development while the southern part is more compact. Eight development trends combining local context are identified, re-confirming the previous findings and highlighting the importance of improving suburban amenities as they suffer from rapid urbanization with limited land and outdated planning. These trends reveal a renewing urban center with gentrification, fast-urbanizing suburbs with lagged planning, sprawling urban edge, and hollowing rural areas. The core city typically exhibits a stable or even

declining urban land use with a high level of urban amenities but outmigration. Such a process may result in two potential sprawl development scenarios. The first is the "false sprawl trend" since the urban centers show decreasing population density but are still at a high compact development level. However, the renewal may drive residents to the suburbs, resulting in potential sprawl development. The second is the two distinct different trends of the suburbs. Traditional suburbs usually show compact development trends but with overwhelming urbanization and underdeveloped urban amenities. Such a phenomenon might be the result of the legacy of the past 20 years, characterized by the transformation of the Danwei system and sprawl development. Emerging suburbs, on the other hand, might show a typical sprawl development pattern with low density and unfulfilled services. While the rural revitalization strategy has yielded remarkable results in China, represented by significant growth in urban amenities and built-up areas in most rural areas, there has been a decrease in population in these rural areas. The contrast can be attributed to the common phenomenon of urbanization of rural populations in Chinese cities. In summary, population growth, urban amenities, and urban land expansion do not align perfectly, resulting in a mismatch that can lead to various challenges in urban development and planning, including unbalanced spatial development patterns, social inequality, environmental degradation, and even worsening urban sprawl.

The regression results further reveal the characteristics of the sprawl development in Wuhan. While sprawl development is driven mainly by overcrowding and urbanization, the influence of outmigration of urban centers with gentrification, the fast-growing urban edges with low-density development, and the urbanizing rural areas with population loss are not to be ignored. This finding suggests that the government should give attention to the under-supplied private service in compact developing regions and the market-based sprawling private service in urban peripheries while adjusting the development trend by implementing government departments and the public transit system. The GWR model further uncovers these linkages' spatial heterogeneity, showing a core-periphery structure with a north-south division that is highly related to Wuhan's planning strategies.

6. Conclusions

Urban sprawl has emerged as a critical issue in contemporary urban planning discourse, particularly in the context of China's rapid urbanization [77]. Despite the growing body of literature on this subject, there is still a pressing need for a more nuanced understanding of sprawl development's local and spatiotemporal aspects. Furthermore, the interplay between urban form, urban amenities, and the implications for urban inequality and quality of life has not been thoroughly explored. This study addresses these gaps by examining the dynamics of sprawl development in Wuhan, Hubei, using remote sensing data and urban open data to provide a fresh and up-to-date perspective on urban spaces.

This study integrates urban amenities into the theoretical framework and provides an in-depth examination of urban sprawl in Wuhan. It introduces urban amenities as the indicator of urban lifestyle, which enriches the traditional view of urban sprawl that measures it with population, land use, and traffic. This approach contributes to understanding the complex characteristics and potential outcomes of sprawl development. While public services and public transit are well-developed in the suburbs, private services are not. Such an imbalance reflects the mixture of top-down and bottom-up development in urban China but also indicates that it is hard to rely on market forces to ensure urban equity in urban quality of life. On the other hand, it is especially important to distribute high-quality public services to suburban areas, which has been identified as a critical issue in urban China [47]. In this regard, this study reveals the importance of these development forces and indicators in sprawl development and calls for further exploration. To address this, urban planners and policymakers should combine top-down and bottom-up forces to improve residents' overall living conditions and quality of life, and urban amenities should be integrated into sustainable development strategies that aim to minimize urban sprawl. For example, creating walkable neighborhoods with diverse services, parks, and recreational facilities

can encourage residents to live, work, and play within the same area, thus reducing the need for long-distance commuting and promoting a more compact urban form [78].

Second, this study characterizes the dynamics and patterns of urban sprawl at an intra-urban scale in the context of China's urbanization. The findings reveal the triple process as the driver of sprawl development in China, including urban renewal, suburbanization, and rural revitalization [77,79,80]. Such a finding challenges the traditional view of harmless urban renewal in urban China, as the outmigration from the core city may contribute to a sprawl development trend in other districts, characterized by an increasing demand for urban amenities and built-up areas, leading to the concern of spatial exclusion and gentrification. Thus, the effects of resettlement of urban renewal should be examined thoroughly. Urban planners require more inclusive planning strategies, which can be achievable by promoting sustainable growth, such as transit-oriented development, mixed-use zoning, and compact city designs that encourage efficient land use and diverse housing options [81].

Further, the legacy of outdated suburban planning has resulted in areas undergoing compact development previously planned as sprawled. The high urbanization pressure, lack of urban amenities, and limited urban land resources contribute to the challenge of managing urban growth in these areas [82]. These circumstances raise concerns about urban inequality and highlight the need for effective governance strategies to address these issues. It also calls for incorporating local context and conditions into urban planning for developing sustainable and effective strategies to address urban sprawl. To achieve this, planners should analyze various local factors, including socio-economic dynamics, demographic trends, cultural aspects, and natural resources. In addition, governance strategies should prioritize participatory decision-making processes involving local communities, stakeholders, and experts in planning and developing suburban areas [83,84].

While rural revitalization leads to massive improvements in infrastructures and services in rural areas, these areas are undergoing tremendous population outmigration. Despite being controversial, these investments are needed since rural livelihoods can be enhanced by investing in both physical and digital infrastructure, enhancing the quality and accessibility of services, and fostering economic, thereby potentially reversing the trend of outmigration. While the measure may not be able to halt exoduses, it creates an environment conducive to growth and development. By prioritizing and expediting rural revitalization efforts, we ensure a balanced demographic landscape that fosters socio-economic equity, cultivates ecosystem quality, and contributes to overall well-being. Future research should focus on devising and implementing these revitalization strategies and assessing their impact on the demographic patterns in rural areas.

While this study offers valuable insights into the characteristics of sprawl development in urban China, it is not without limitations. First, a more accurate land use division, such as dividing commercial, residential, and industrial land, could provide a more comprehensive view of land use mixture and urban function. In our case, this study utilizes remote sensing data and uses land cover to represent land use; thus further differentiating these urban land uses is difficult. Future studies should consider urban land use and function variations and explore how they contribute to sprawl development. Second, due to methodological limitations, this paper primarily adopts a top-down quantitative data-driven approach, and there is a lack of in-depth fieldwork to understand urban spaces' dynamics further. Incorporating qualitative methods, such as interviews and fieldwork, in subsequent studies will provide valuable insights into the dynamics of urban sprawl in a more localized context.

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References

1. Wei, Y.H.D.; Ewing, R. Urban expansion, sprawl and inequality. *Landsc. Urban Plan.* **2018**, *177*, 259–265. [CrossRef]
2. Carneiro, E.; Lopes, W.; Espindola, G. Linking Urban Sprawl and Surface Urban Heat Island in the Teresina–Timon Conurbation Area in Brazil. *Land* **2021**, *10*, 516. [CrossRef]
3. Yang, X.; Wang, J.; Cao, J.; Ren, S.; Ran, Q.; Wu, H. The spatial spillover effect of urban sprawl and fiscal decentralization on air pollution: Evidence from 269 cities in China. *Empir. Econ.* **2022**, *63*, 847–875. [CrossRef]
4. Guo, C.; Buchmann, C.M.; Schwarz, N. Linking urban sprawl and income segregation—Findings from a stylized agent-based model. *Environ. Plan. B Urban Anal. City Sci.* **2019**, *46*, 469–489. [CrossRef]
5. Deng, Y.; Qi, W.; Fu, B.; Wang, K. Geographical transformations of urban sprawl: Exploring the spatial heterogeneity across cities in China 1992–2015. *Cities* **2020**, *105*, 102415. [CrossRef]
6. Qin, X.; Wei, Y.D.; Yu, Z.; Xiong, N. Urbanization, Suburbanization, and Population Redistribution in Urban China: A Case Study of Nanjing. *J. Urban Plan. Dev.* **2022**, *148*, 05022034. [CrossRef]
7. Zhang, X.; Shen, J.; Sun, Y.; Zhou, C.; Yang, Y. Formation of City Regions from Bottom-up Initiatives: Investigating Coalitional Developmentalism in the Pearl River Delta. *Ann. Am. Assoc. Geogr.* **2023**, *113*, 700–716. [CrossRef]
8. Zhang, X.; Li, Y.; Zhou, C.; Luan, X.; Yuan, F. Rescaling of the land regime in the making of city-regions: A case study of China's Pearl River Delta. *Urban Stud.* **2023**, *60*, 483–500. [CrossRef]
9. Walker, R.A. A theory of suburbanization: Capitalism and the construction of urban space in the United States. In *Urbanization and Urban Planning in Capitalist Society*; Routledge: London, UK, 2018; pp. 383–429.
10. Byun, P.; Esparza, A.X. A Revisionist Model of Suburbanization and Sprawl. *J. Plan. Educ. Res.* **2016**, *24*, 252–264. [CrossRef]
11. Ismael, H.M. Urban form study: The sprawling city—Review of methods of studying urban sprawl. *GeoJournal* **2020**, *86*, 1785–1796. [CrossRef]
12. Wang, X.; Shi, R.; Zhou, Y. Dynamics of urban sprawl and sustainable development in China. *Socio-Econ. Plan. Sci.* **2020**, *70*, 100736. [CrossRef]
13. Midler, M.; Dubcova, A. Commercial Suburbanization of Nitra City (Case Study Cerman District). In Proceedings of the 24th International PhD Students Conference (MendelNet 2017), Brno, Czech Republic, 8–9 November 2017; pp. 407–412.
14. Mera, K.; Renaud, B. *Asia's Financial Crisis and the Role of Real Estate*; Routledge: London, UK, 2016.
15. Eren, F. Does the Asian property market work for sustainable urban developments? In *Sustainable Cities in Asia*; Routledge: London, UK, 2017; pp. 32–47.
16. Liu, Y.; Fan, P.; Yue, W.; Song, Y. Impacts of land finance on urban sprawl in China: The case of Chongqing. *Land Use Policy* **2018**, *72*, 420–432. [CrossRef]
17. Zhao, P. Managing urban growth in a transforming China: Evidence from Beijing. *Land Use Policy* **2011**, *28*, 96–109. [CrossRef]
18. Jia, M.; Liu, Y.; Lieske, S.N.; Chen, T. Public policy change and its impact on urban expansion: An evaluation of 265 cities in China. *Land Use Policy* **2020**, *97*, 104754. [CrossRef]
19. Frederic Deng, F.; Huang, Y. Uneven land reform and urban sprawl in China: The case of Beijing. *Prog. Plan.* **2004**, *61*, 211–236. [CrossRef]
20. Yan, Y.; Liu, T.; Wang, N.; Yao, S. Urban sprawl and fiscal stress: Evidence from urbanizing China. *Cities* **2022**, *126*, 103699. [CrossRef]
21. Wu, J.; Yu, Z.; Wei, Y.D.; Yang, L. Changing distribution of migrant population and its influencing factors in urban China: Economic transition, public policy, and amenities. *Habitat Int.* **2019**, *94*, 102063. [CrossRef]
22. Wang, X. Relationship between Population Urbanization and Urban Sprawl Across Different City Sizes in China. *Environ. Urban. ASIA* **2021**, *12*, 202–219. [CrossRef]
23. Liu, Y.; Zhou, Y. Territory spatial planning and national governance system in China. *Land Use Policy* **2021**, *102*, 105288. [CrossRef]
24. Yang, Y.; Zhang, L.; Ye, Y.; Wang, Z. Curbing Sprawl with Development-limiting Boundaries in Urban China: A Review of Literature. *J. Plan. Lit.* **2020**, *35*, 25–40. [CrossRef]
25. Bhatta, B.; Saraswati, S.; Bandyopadhyay, D. Urban sprawl measurement from remote sensing data. *Appl. Geogr.* **2010**, *30*, 731–740. [CrossRef]
26. Frenkel, A.; Ashkenazi, M. Measuring Urban Sprawl: How Can We Deal with It? *Environ. Plan. B Plan. Des.* **2008**, *35*, 56–79. [CrossRef]
27. Oueslati, W.; Alvanides, S.; Garrod, G. Determinants of urban sprawl in European cities. *Urban Stud.* **2015**, *52*, 1594–1614. [CrossRef] [PubMed]
28. Ewing, R.; Hamidi, S. Compactness versus Sprawl:A Review of Recent Evidence from the United States. *J. Plan. Lit.* **2015**, *30*, 413–432. [CrossRef]
29. Wu, Y.; Wei, Y.D.; Liu, M. Urban Form and Spatiotemporal Vulnerability of Local Communities to COVID-19. *Geogr. Rev.* **2022**, 1–20. [CrossRef]

30. Wei, Y.H.D. Planning Chinese cities: The limits of transitional institutions. *Urban Geogr.* **2005**, *26*, 200–221. [CrossRef]
31. Kim, J. Eating outdoors: An inscription–prescription analysis of user behaviour in public spaces. *Urban Des. Int.* **2019**, *24*, 280–295. [CrossRef]
32. Zhou, L.; Dang, X.; Sun, Q.; Wang, S. Multi-scenario simulation of urban land change in Shanghai by random forest and CA-Markov model. *Sustain. Cities Soc.* **2020**, *55*, 102045. [CrossRef]
33. Bertaud, A. Order without design: How markets shape cities. *Town Reg. Plan.* **2021**, *79*, 2–5.
34. He, Q.; Musterd, S.; Boterman, W. Geographical structure of the local segregation of migrants in (sub)urban China. *GeoJournal* **2023**, *88*, 1449–1467. [CrossRef]
35. Wu, F. Scripting Indian and Chinese urban spatial transformation: Adding new narratives to gentrification and suburbanisation research. *Environ. Plan. C Politics Space* **2020**, *38*, 980–997. [CrossRef]
36. Surya, B.; Salim, A.; Hernita, H.; Suriani, S.; Menne, F.; Rasyidi, E.S. Land Use Change, Urban Agglomeration, and Urban Sprawl: A Sustainable Development Perspective of Makassar City, Indonesia. *Land* **2021**, *10*, 556. [CrossRef]
37. Glaeser, E.L.; Kourtit, K.; Nijkamp, P. *Urban Empires Cities as Global Rulers in the New Urban World*; Routledge: New York, NY, USA, 2020.
38. Wu, W.; Chen, W.Y.; Yun, Y.; Wang, F.; Gong, Z. Urban greenness, mixed land-use, and life satisfaction: Evidence from residential locations and workplace settings in Beijing. *Landsc. Urban Plan.* **2022**, *224*, 104428. [CrossRef]
39. Chen, J.; Gao, J.; Yuan, F.; Wei, Y. Spatial Determinants of Urban Land Expansion in Globalizing Nanjing, China. *Sustainability* **2016**, *8*, 868. [CrossRef]
40. Varade, D.; Singh, H.; Singh, A.P.; Awasthi, S. Assessment of urban sprawls, amenities, and indifferences of LST and AOD in sub-urban area: A case study of Jammu. *Environ. Sci. Pollut. Res.* **2023**. [CrossRef]
41. Zhu, W.; Wang, J.; Qin, B. Quantity or quality? Exploring the association between public open space and mental health in urban China. *Landsc. Urban Plan.* **2021**, *213*, 104128. [CrossRef]
42. Xiao, W.; Wei, Y.D. Assess the non-linear relationship between built environment and active travel around light-rail transit stations. *Appl. Geogr.* **2023**, *151*, 102862. [CrossRef]
43. He, J.; Song, Y.; Huang, X.; Lin, J. An amenity-based approach to excellent returning scientists' location choice in China. *Pap. Reg. Sci.* **2022**, *101*, 1181–1197. [CrossRef]
44. Zhang, S.; Zheng, H.; Zhou, H.; Shao, Q.; Wu, Q. Sustainable land urbanization, urban amenities, and population urbanization: Evidence from city-level data in China. *Soc. Sci. Q.* **2021**, *102*, 1686–1698. [CrossRef]
45. Wang, M. Polycentric urban development and urban amenities: Evidence from Chinese cities. *Environ. Plan. B Urban Anal. City Sci.* **2020**, *48*, 400–416. [CrossRef]
46. Xia, C.; Yeh, A.G.-O.; Zhang, A. Analyzing spatial relationships between urban land use intensity and urban vitality at street block level: A case study of five Chinese megacities. *Landsc. Urban Plan.* **2020**, *193*, 103669. [CrossRef]
47. Li, H.; Wei, Y.D.; Wu, Y.; Tian, G. Analyzing housing prices in Shanghai with open data: Amenity, accessibility and urban structure. *Cities* **2019**, *91*, 165–179. [CrossRef]
48. Gazzeh, K.; Abubakar, I.R. Regional disparity in access to basic public services in Saudi Arabia: A sustainability challenge. *Util. Policy* **2018**, *52*, 70–80. [CrossRef]
49. Wu, Y.; Wei, Y.D.; Li, H.; Liu, M. Amenity, firm agglomeration, and local creativity of producer services in Shanghai. *Cities* **2022**, *120*, 103421. [CrossRef]
50. Long, Y.; Gao, S. Shrinking cities in China: The overall profile and paradox in planning. In *Shrinking Cities in China: The Other Facet of Urbanization*; Springer: Singapore, 2019; pp. 3–21.
51. Zhu, X.; Yao, D.; Shi, H.; Qu, K.; Tang, Y.; Zhao, K. The Evolution Mode and Driving Mechanisms of the Relationship between Construction Land Use and Permanent Population in Urban and Rural Contexts: Evidence from China's Land Survey. *Land* **2022**, *11*, 1721. [CrossRef]
52. Shao, Z.; Sumari, N.S.; Portnov, A.; Ujoh, F.; Musakwa, W.; Mandela, P.J. Urban sprawl and its impact on sustainable urban development: A combination of remote sensing and social media data. *Geo-Spat. Inf. Sci.* **2021**, *24*, 241–255. [CrossRef]
53. Wang, Q.; Wang, H. Spatiotemporal dynamics and evolution relationships between land-use/land cover change and landscape pattern in response to rapid urban sprawl process: A case study in Wuhan, China. *Ecol. Eng.* **2022**, *182*, 106716. [CrossRef]
54. Long, Y.; Song, Y.; Chen, L. Identifying subcenters with a nonparametric method and ubiquitous point-of-interest data: A case study of 284 Chinese cities. *Environ. Plan. B Urban Anal. City Sci.* **2021**, *49*, 58–75. [CrossRef]
55. Qin, B.; Zhang, Y. Note on urbanization in China: Urban definitions and census data. *China Econ. Rev.* **2014**, *30*, 495–502. [CrossRef]
56. Espindola, G.M.d.; Carneiro, E.L.N.d.C.; Façanha, A.C. Four decades of urban sprawl and population growth in Teresina, Brazil. *Appl. Geogr.* **2017**, *79*, 73–83. [CrossRef]
57. Chen, D.; Lu, X.; Liu, X.; Wang, X. Measurement of the eco-environmental effects of urban sprawl: Theoretical mechanism and spatiotemporal differentiation. *Ecol. Indic.* **2019**, *105*, 6–15. [CrossRef]
58. Zhang, L.; Wei, Y.; Meng, R. Spatiotemporal Dynamics and Spatial Determinants of Urban Growth in Suzhou, China. *Sustainability* **2017**, *9*, 393. [CrossRef]
59. Feng, Y.; Liu, Y.; Tong, X. Spatiotemporal variation of landscape patterns and their spatial determinants in Shanghai, China. *Ecol. Indic.* **2018**, *87*, 22–32. [CrossRef]

60. Wuhan Bureau of Statistics. *Wuhan Statistical Yearbook*; Wuhan Bureau of Statistics: Wuhan, China, 2016; pp. 3–4.
61. Wuhan Bureau of Statistics. *Wuhan Statistical Yearbook*; Wuhan Bureau of Statistics: Wuhan, China, 2022; pp. 3–4.
62. Zhou, K.; Tan, R. More Than Thirty Years of Environmentally Sensitive Area Loss in Wuhan: What Lessons Have We Learned from Urban Containment Policy? *Land* **2022**, *11*, 1310. [CrossRef]
63. Jiao, H.; Li, C.; Yu, Y.; Peng, Z. Urban Public Green Space Equity against the Context of High-Speed Urbanization in Wuhan, Central China. *Sustainability* **2020**, *12*, 9394. [CrossRef]
64. Micijevic, E.; Haque, M.O.; Scaramuzza, P.; Storey, J.; Anderson, C.; Markham, B.; Neeck, S.P.; Kimura, T.; Martimort, P. Landsat 9 pre-launch sensor characterization and comparison with Landsat 8 results. In Proceedings of the Sensors, Systems, and Next-Generation Satellites XXIII, Strasbourg, France, 9–12 September 2019.
65. Butler, J.J.; Xiong, X.; Gu, X.; Markham, B.L.; Jenstrom, D.; Masek, J.G.; Dabney, P.; Pedelty, J.A.; Barsi, J.A.; Montanaro, M. Landsat 9: Status and plans. In Proceedings of the Earth Observing Systems XXI, San Diego, CA, USA, 28 August–1 September 2016.
66. Milias, V.; Psyllidis, A. Assessing the influence of point-of-interest features on the classification of place categories. *Comput. Environ. Urban Syst.* **2021**, *86*, 101597. [CrossRef]
67. Glaeser, E.L.; Kolko, J.; Saiz, A. Consumer city. *J. Econ. Geogr.* **2000**, 27–50.
68. Calka, B.; Bielecka, E. Reliability Analysis of LandScan Gridded Population Data. The Case Study of Poland. *ISPRS Int. J. Geo-Inf.* **2019**, *8*, 222. [CrossRef]
69. Xu, H. Modification of normalised difference water index (NDWI) to enhance open water features in remotely sensed imagery. *Int. J. Remote Sens.* **2006**, *27*, 3025–3033. [CrossRef]
70. Huang, S.; Tang, L.; Hupy, J.P.; Wang, Y.; Shao, G. A commentary review on the use of normalized difference vegetation index (NDVI) in the era of popular remote sensing. *J. For. Res.* **2021**, *32*, 1–6. [CrossRef]
71. Zheng, Y.; Tang, L.; Wang, H. An improved approach for monitoring urban built-up areas by combining NPP-VIIRS nighttime light, NDVI, NDWI, and NDBI. *J. Clean. Prod.* **2021**, *328*, 129488. [CrossRef]
72. Feng, Y.; Wang, X.; Du, W.; Liu, J.; Li, Y. Spatiotemporal characteristics and driving forces of urban sprawl in China during 2003–2017. *J. Clean. Prod.* **2019**, *241*, 118061. [CrossRef]
73. Murakami, D.; Griffith, D.A. Eigenvector Spatial Filtering for Large Data Sets: Fixed and Random Effects Approaches. *Geogr. Anal.* **2019**, *51*, 23–49. [CrossRef]
74. Zhu, C.; Zhang, X.; Zhou, M.; He, S.; Gan, M.; Yang, L.; Wang, K. Impacts of urbanization and landscape pattern on habitat quality using OLS and GWR models in Hangzhou, China. *Ecol. Indic.* **2020**, *117*, 106654. [CrossRef]
75. Liu, Y.; Shu, L.; Peng, L. The Hollowing Process of Rural Communities in China: Considering the Regional Characteristic. *Land* **2021**, *10*, 911. [CrossRef]
76. Li, Q.; Xu, Y.; Yang, X.; Chen, K. Unveiling the Regional Differences and Convergence of Urban Sprawl in China, 2006–2019. *Land* **2023**, *12*, 152. [CrossRef]
77. Yaping, W.; Min, Z. Urban spill over vs. local urban sprawl: Entangling land-use regulations in the urban growth of China's megacities. *Land Use Policy* **2009**, *26*, 1031–1045. [CrossRef]
78. Barnett, A.; Van Dyck, D.; Van Cauwenberg, J.; Zhang, C.J.P.; Lai, P.C.; Cerin, E. Objective neighbourhood attributes as correlates of neighbourhood dissatisfaction and the mediating role of neighbourhood perceptions in older adults from culturally and physically diverse urban environments. *Cities* **2020**, *107*, 102879. [CrossRef]
79. Ingersoll, R. *Sprawltown: Looking for the City on Its Edges*; Princeton Architectural Press: Hudson, NY, USA, 2006.
80. Zhuang, T.; Qian, Q.K.; Visscher, H.J.; Elsinga, M.G. Stakeholders' Expectations in Urban Renewal Projects in China: A Key Step towards Sustainability. *Sustainability* **2017**, *9*, 1640. [CrossRef]
81. Wu, Y.; Wei, Y.D.; Li, H. Firm Suburbanization in the Context of Urban Sprawl: Neighborhood Effect and Sectoral Difference. *Prof. Geogr.* **2020**, *72*, 598–617. [CrossRef]
82. Yuan, F.; Wu, J.W.; Wei, Y.H.D.; Wang, L. Policy change, amenity, and spatiotemporal dynamics of housing prices in Nanjing, China. *Land Use Policy* **2018**, *75*, 225–236. [CrossRef]
83. Jankowski, P. Towards participatory geographic information systems for community-based environmental decision making. *J. Environ. Manag.* **2009**, *90*, 1966–1971. [CrossRef]
84. Li, W.; Feng, T.; Timmermans, H.J.P.; Li, Z.; Zhang, M.; Li, B. Analysis of citizens' motivation and participation intention in urban planning. *Cities* **2020**, *106*, 102921. [CrossRef]