



Article

# Multi-Source Data-Driven Brownfield Identification: Methodology and Spatial Characteristics of Third Line Construction Cities

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Received: 2 February 2026

Revised: 31 March 2026

Accepted: 31 March 2026

Published: 7 April 2026

**Abstract:** Global practices in brownfield redevelopment have yielded valuable legislative and policy frameworks. However, existing studies lack targeted identification and database construction methodologies for Third Line Construction cities in China, which feature clustered industrial heritage and fragmented land rights, leading to a disconnect between general brownfield research and the actual governance needs of such typical industrial cities. This study addresses these gaps by developing a multi-source data integrated technical framework for systematic brownfield identification and standardized database construction, taking Mianyang—a typical Third Line Construction city—as the case. The framework prioritizes planning data, takes Point of Interest (POI) data as the core supplement, and innovatively integrates satellite imagery and industrial statistics via cross-year POI superimposition-deduplication, coordinate reverse geocoding verification, and ArcGIS-based polygon boundary delineation, effectively compensating for traditional method deficiencies and realizing standardized attribute-spatial data binding. Applying this framework, 599 brownfield sites (9234.83 ha) in Mianyang were identified and classified into four functional categories. Spatial statistical analysis reveals their concentration in Fucheng District and beyond the Second Ring Road, dominance of large-scale plots, and functional differentiation with nearly half remaining polluting industrial land. This study establishes a standardized, replicable process for Third Line Construction cities and a quantitative paradigm for brownfield precise governance.

**Keywords:** multi-source data integration; POI data; spatial analysis; brownfield database construction; industrial heritage cities

## 1. Introduction

The concept of “brownfields” was first defined by the United States Superfund Act in the 1980s [1]. Brownfields generally refer to lands that were previously used for industrial or commercial purposes but have since been abandoned, left idle, or underutilized, and whose expansion, redevelopment, or reuse may be affected by actual or potential environmental pollution, such as heavy metals, organic pollutants, and the like. The scientific, efficient, and sustainable regeneration and utilization of brownfields has evolved from a narrowly defined environmental governance issue into a comprehensive strategic concern encompassing urban spatial restructuring, economic transformation, social equity, and the construction of an ecological civilization. Internationally, from the International Building Exhibition Emscher Park in Germany’s Ruhr region to the Brownfields Action Agenda in the United States, governments and academic circles across various countries have accumulated extensive



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experience in brownfield redevelopment through legislation, policy incentives, and practical exploration. These efforts demonstrate that brownfield regeneration can not only eliminate environmental hazards and revitalize existing land but also generate significant economic, social, and ecological benefits [2].

Over the past four decades, China has experienced the largest and fastest urbanization process in world history, accompanied by dramatic urban spatial expansion and industrial upgrading. Unlike the gradual deindustrialization experienced by Western countries, China's brownfield issue exhibits unique characteristics, such as rapid formation, complex pollution types, intertwined property rights, and a lack of data and information, all of which make governance and reuse more challenging [3]. Mianyang, as a key city strategically positioned during China's First Five-Year Plan and Third Line Construction periods, was once densely populated with factories and enterprises in industries such as military, electronics, machinery, and textiles [4]. Research on brownfield identification and database establishment in Mianyang is therefore highly representative.

Currently, some scholars have analyzed the commercial spatial pattern and industrial distribution in Mianyang's central urban area based on Point of Interest (POI) data [5] and explored the characteristics of urban residential spatial distribution in the city [6]. Other studies have concentrated on the ecological security pattern or the spatiotemporal characteristics of shared bicycles in Mianyang [7]. Although these studies have depicted the urban space of Mianyang from different perspectives, none of them has taken "brownfields" as the core research object, and there is a lack of systematic exploration on brownfield identification methods, spatial distribution characteristics and reuse potential targeting the city's Third Line Construction industrial background.

Therefore, this study intends to take the central urban area of Mianyang as an example to explore the identification of urban brownfields in developing countries. Specifically, this study makes scientific advancements by developing a multi-source data integrated technical framework for brownfield identification and standardized database construction, which takes planning data as the priority and POI data as the core supplement, and innovatively integrates satellite imagery and industrial statistics. This framework effectively compensates for the deficiencies of traditional brownfield identification methods, such as difficulty in large-scale investigation and imprecise location confirmation.

## 2. Methods

### 2.1. Brownfield Identification

Traditional data sources for brownfield identification mainly include various versions of planning maps and current situation maps [8]; enterprise lists, environmental reports, and payment reports [9]; as well as statistical data, municipal chronicles, urban yearbooks, academic papers [10], etc. However, these data have the following issues: ① It is difficult to conduct identification at the city level or above; ② It is challenging to identify smaller-scale brownfields; ③ It is hard to obtain information on plot contamination; ④ It is difficult to confirm the specific location and extent of brownfields.

In recent years, big data has been applied in urban planning [11] and the identification of functional areas [12]. Among the types of big data, Point of Interest (POI) data is more frequently utilized [13]. This kind of data describes the spatial and attribute information of geographical entities, such as the names, addresses, and coordinates of entities, and offers the advantages of a large sample size and detailed information coverage. POI data can cover an entire city, with information precise down to individual enterprise stores, and contains enterprise names and location information, enabling it to compensate for the shortcomings of current brownfield identification methods.

In this study, POI data is given priority after planning data and is placed at the second level of the identification framework (Figure 1). Existing POI data was utilized, encompassing Baidu POI data Excel sheets for the city of Mianyang from the years 2012 and 2023. These sheets included headers with information such as enterprise name, type, telephone number, administrative division, geographical coordinates, and address. From these tables, fields categorized as "factory", "gas station", "waste recycling station", and similar types were extracted separately. The data of the two years was then superimposed, and entries with identical enterprise names were removed to obtain the identification results. Each identified enterprise was subsequently queried individually, and through reverse geocoding of coordinates combined with historical satellite remote sensing imagery and panoramic views, the abandonment of the sites was confirmed, along with the approximate delineation of their boundaries. The resulting data represents enterprises that have relocated or ceased operations, that is, brownfield plots that meet the conditions of being abandoned, idle, or subject to production restrictions. The brownfields thus identified mainly encompass three categories: abandoned industrial lands, landfill sites, and abandoned transportation facilities. Among them, industrial lands comprise two types: general industrial lands and industrial heritage lands from the Third Line Construction.

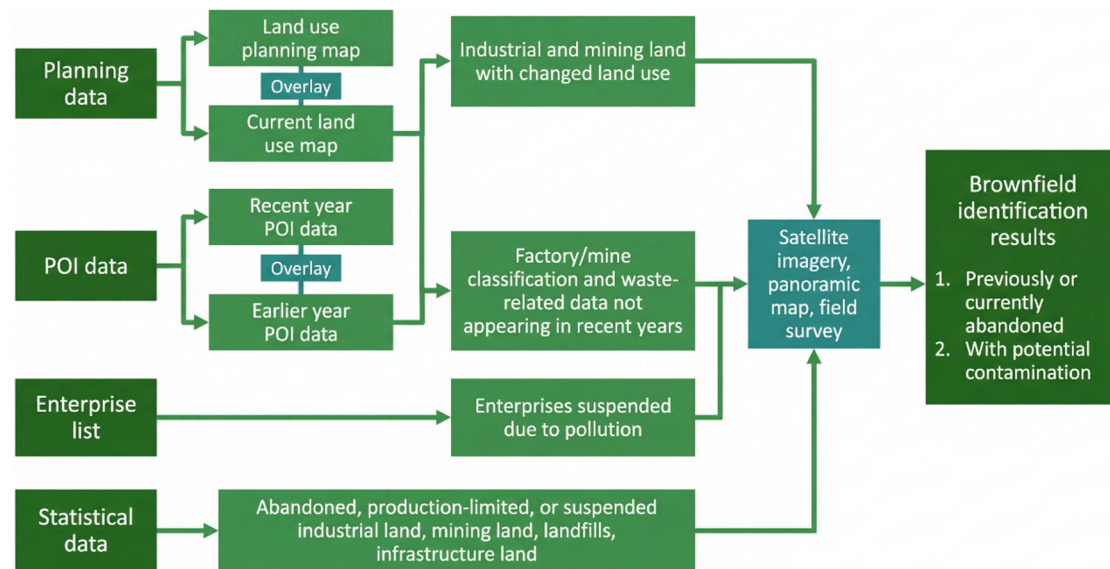


Figure 1. Brownfield identification process.

## 2.2. Brownfield Database Construction

Among the identification results of the three categories of brownfields, the POI data, enterprise lists, and statistical data are stored in Excel spreadsheets, while the planning data is in raster image files. This study utilizes ArcGIS software to manually delineate the scope of brownfields in the form of polygon features and inputs information such as enterprise names, administrative regions, coordinates, addresses, and brownfield types into the attribute table of the polygon features for data storage purposes.

When constructing the database, priority should give to processing and inputting brownfield data from Excel spreadsheets to avoid redundant data entry. The first step involves data processing. The Excel spreadsheets are simplified by deleting redundant fields from the POI data, retaining only enterprise names, administrative regions, coordinates, addresses, and brownfield type information. A new field is created for numbering all data entries to facilitate subsequent attribute table connections. The second step is mapping importation. Road network and water system data within the study area are imported into ArcGIS in TIF format, and the splicing function of the Universal Electronic Map Downloader is utilized to accurately position and splice clear satellite maps of the study area using the “Georeferencing” function. The third step is brownfield data entry. Brownfield locations are determined by inputting coordinates into the Baidu Map Coordinate Picking System for reverse coordinate lookup. Baidu Map is one of China’s most widely used map and navigation services, and its coordinate picking feature enables precise positioning based on known latitude and longitude coordinates. In this study, this functionality was primarily utilized to verify the authenticity of the coordinate data within the POI dataset. New fields are created in the attribute table, and based on satellite remote sensing images, panoramic views, and enterprise information, the scope of brownfields is delineated, and brownfield plots are marked as “Y1”, “Y2”, “Y3”, or “Y4” according to their current status. Another new field is created to match brownfield entries with their corresponding numbers in the Excel spreadsheet. In the attribute table, select “Table Options—Joins and Relates—Join” and use the brownfield number as the join field to match the Excel data to the attribute table.

After inputting the Excel spreadsheet files, raster image files are then processed. The raster image files are imported into ArcGIS and georeferenced. New polygon features are created based on brownfield categories and generation time periods, and the scope of brownfields is delineated according to the raster images. After completing the identification process, a reverse check was conducted to verify whether the brownfield areas indicated by the data in the Excel sheets fell within the boundaries specified in the planning maps, ensuring the authenticity of all data. Finally, new fields are created in the attribute table, and brownfield plots are marked as “Y1”, “Y2”, “Y3”, or “Y4” based on satellite remote sensing images and panoramic views according to their current status.

## 3. Materials

### 3.1. Third Line Construction Area

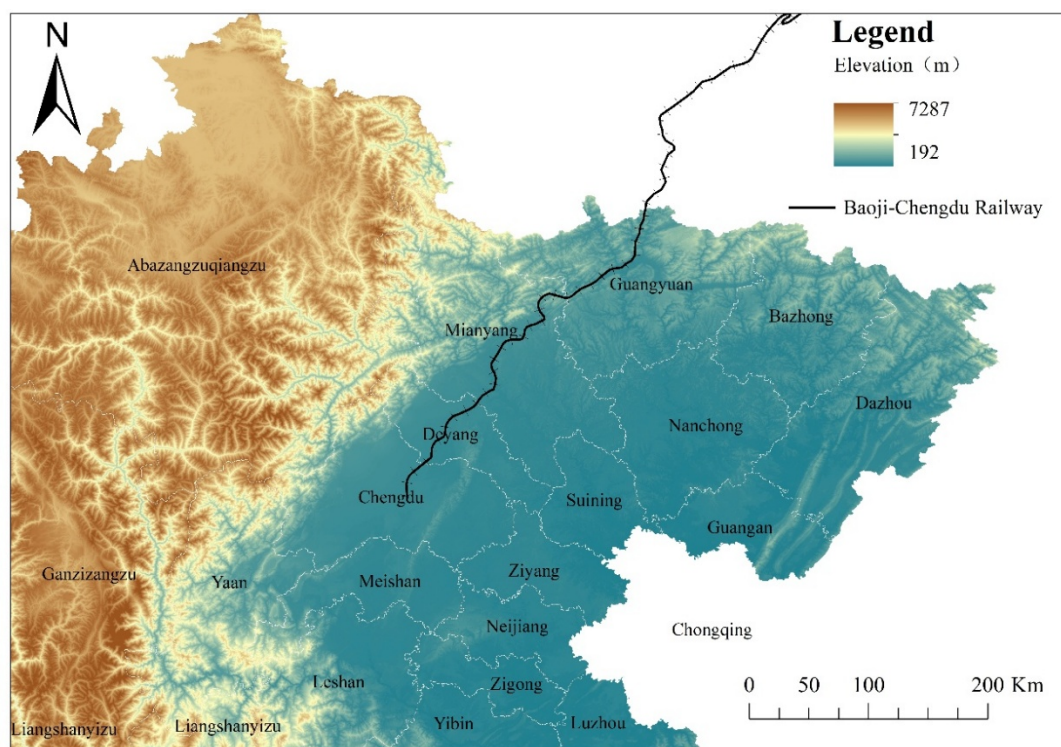
From the mid-1960s to the early 1980s, China launched a large-scale campaign for the construction of national defense, science and technology, industrial, and transportation infrastructure, with war preparedness as its

core guiding ideology [14]. This historical movement is known as the Third Line Construction. The so-called Third Line referred to China's strategic rear areas directly invested in and constructed by the state, covering an extremely vast geographical expanse [15]. Among them, Sichuan Province, due to its unique basin topography and strategic depth, became the core region with the most concentrated investment and the largest scale of Third Line Construction [16]. The site selection for Third Line Construction projects adhered to the principles of "being close to mountains, decentralized, and concealed" [17]. Consequently, a large number of factories, scientific research institutions, and even entire cities were built in remote mountainous areas or valleys, forming a unique industrial landscape.

As times changed, the original Third Line enterprises generally faced survival difficulties owing to their remote geographical locations, outdated technical equipment, and management models that were out of touch with the market economy. A large number of enterprises either went bankrupt and closed down or relocated and adjusted, leaving behind numerous abandoned or idle industrial plants, infrastructure facilities, and living quarters at their original sites.

### 3.2. Mianyang City

Mianyang City is situated in the southwestern part of China, slightly north of the central region of Sichuan Province (Figure 2) [18]. Its geographical coordinates range from 30°42'–33°03' north latitude and 103°45'–105°43' east longitude [19]. The terrain and landforms are complex and diverse, with the Longmen Mountains in the northwest standing tall and the southeast being an extension of the Chengdu Plain, which is relatively flat. This creates a transitional zone from high mountains to hills and then to plains, with a significant elevation difference ranging from approximately 300–5000 m [20]. This unique geographical pattern not only endows Mianyang with abundant natural resources but also provides a natural barrier that made it a strategic rear area during specific historical periods.



**Figure 2.** Schematic diagram of the geographical conditions of Mianyang City.

In terms of regional economy, Mianyang occupies a pivotal position. It is located within the core radiation zone of the Chengdu-Chongqing Twin-City Economic Circle and serves as a crucial transportation node connecting Chengdu with northern Sichuan and even the northwestern regions [21]. The Baoji-Chengdu Railway runs through Mianyang, making it an important corridor linking southwest and northwest China. This transportation advantage was highly valued by the central government during the Third Line Construction period [22], leading to the relocation or establishment of over 40 top-tier defense enterprises and military research institutions in Mianyang from various parts of the country [23]. As the city expanded, some early factories located in the main urban area were gradually relocated, and the land at their original sites became a focal point for urban renewal, forming typical brownfields.

Given Mianyang's industrial history, characterized by electronics, machinery manufacturing, chemical engineering, and the nuclear industry, the primary types of pollutants in its brownfields may include heavy metals, organic pollutants, and radioactive residues [24]. However, similar to many Third Line cities in China, research on brownfield identification in Mianyang is quite limited. With urban development and increasingly stringent environmental protection requirements, the management and redevelopment of these brownfields are facing significant challenges.

### 3.3. Study Area

Mianyang City covers an area of approximately 20,200 km<sup>2</sup> [25]. Due to the site selection principles of the Third Front Construction, some of Mianyang's industrial heritage sites from this period are scattered across mountainous regions with favorable ecological conditions. Considering the varying degrees of urgency in ecological value transformation, brownfield identification should initially focus on central urban areas with the highest population density and relatively fewer green spaces. Therefore, this study designates the brownfield identification scope to include Fucheng District, Youxian District, and Anzhou District within the urban area of Mianyang (Figure 3). Fucheng District is the core urban area of Mianyang, where a large number of old industrial plants and urban built-up areas are concentrated, making it the main area for brownfield distribution. Adjacent to Fucheng District, Youxian District has a relatively low density of brownfield sites, which are mostly small and medium-sized scattered industrial plots. The brownfield sites in Anzhou District are characterized by a distribution pattern of large area and low density, with plot types dominated by large comprehensive parks and industrial land, covering a total area of 3784.79 km<sup>2</sup>.



Figure 3. Study area.

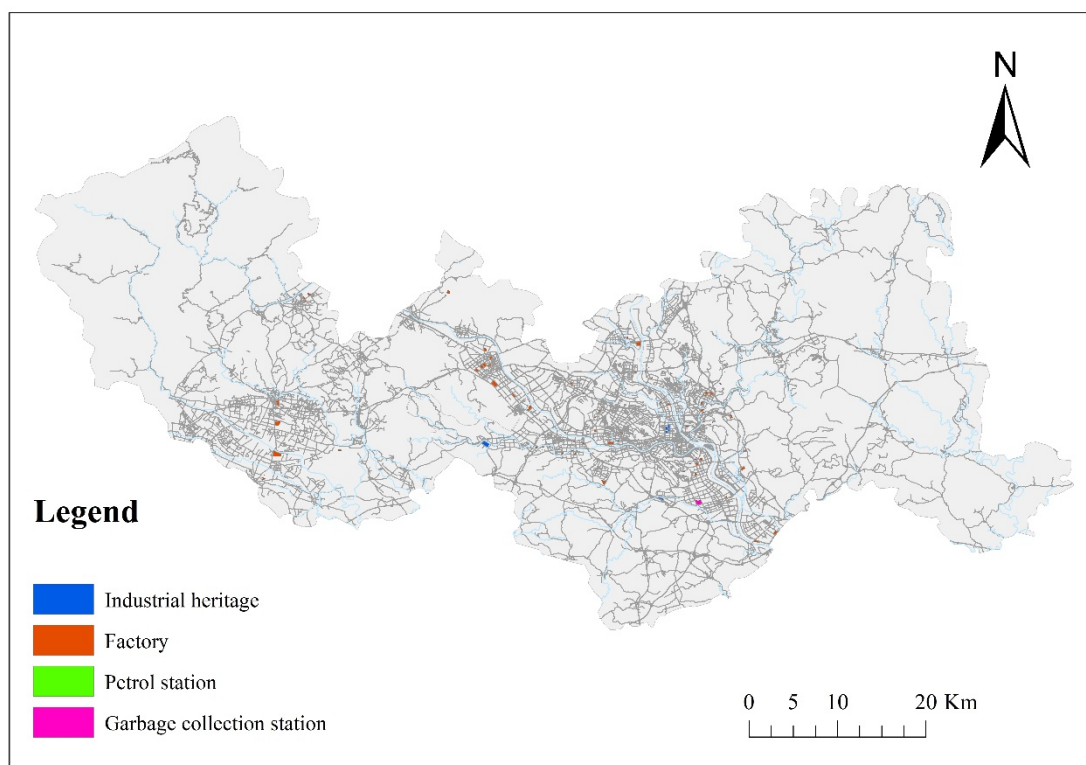
## 4. Results

The data sources for identifying the four categories of brownfields in Mianyang are presented in Table 1. Among them, land use planning data (Data 1) was utilized to identify the planned industrial land areas in Mianyang across different years and stages. The POI data for enterprise factories (Data 2) was employed to identify information on factories, waste stations, and recycling stations in Mianyang; through superimposition and deduplication, the POI data for abandoned factories, waste stations, and recycling stations was obtained to delineate the brownfield scope. The POI data for automotive services (Data 3) was used to identify information on gas stations in Mianyang; similarly, the brownfield scope for gas stations in Mianyang was determined through superimposition and deduplication. Industrial land statistical data (Data 4) was utilized to identify the brownfield scope of industrial heritage from the Third Front Construction. Current satellite imagery (Data 5) was used in conjunction with the aforementioned Data 2, 3, and 4 to identify relevant brownfield sites in Mianyang, including factories, waste recycling stations, gas stations, and industrial heritage sites.

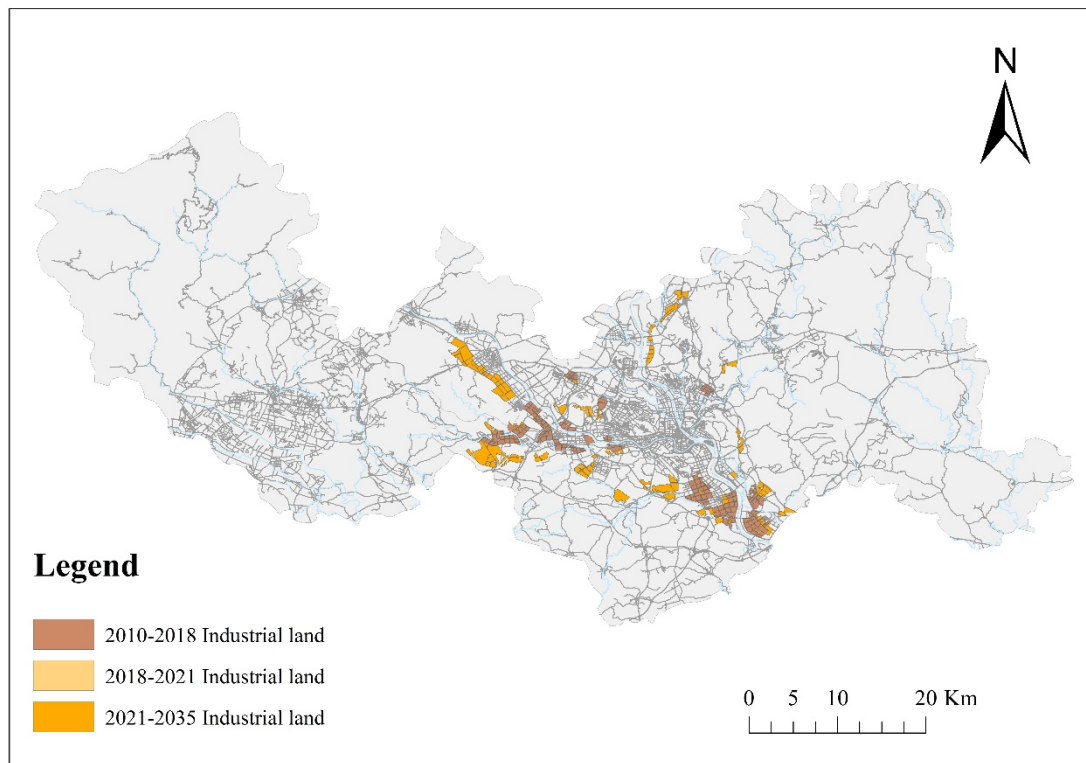
**Table 1.** Construction of the brownfield database.

No.	Data Category	Data Content	Data Format
1	Land use planning data	Comprehensive land use maps of Mianyang City (1997–2010); master plan maps of Mianyang City (2010–2020); land use data of Mianyang City in 2018 [26]; overall land spatial planning of Mianyang City (2021–2035)	Planning map SHP files
2	Enterprise factory POI data	POI data for enterprise factories in Mianyang City (2012 and 2023), with headers including: enterprise name, type, phone number, administrative division, geographic coordinates, address, etc.	Excel sheets
3	Automotive service POI data	POI data for automotive services in Mianyang City (2012 and 2023), with headers including: enterprise name, type, phone number, administrative division, geographic coordinates, address, etc.	Excel sheets
4	Industrial land statistical Data	Inventory of industrial heritage from the Third Front Construction in Mianyang City; relevant papers on the Third Front Construction in Mianyang [27,28]	Inventory documents; academic papers
5	Current satellite imagery	Current satellite imagery of the central urban area of Mianyang City (created by combining satellite remote sensing images with the stitching function of the maps)	Satellite map TIF files

After all brownfield data were input into the ArcGIS 10.8 software, select “Table Options—Joins and Relates—Join” in the attribute table. Using the brownfield number as the join field, the Excel data was matched to the attribute table. At this point, the input of the Excel spreadsheet file was complete (Figure 4).

**Figure 4.** Input results for the Excel spreadsheet file.

The next step involved importing raster image files. The raster image files were imported into ArcGIS and register them using the “Georeferencing” function. New polygon features were created based on brownfield categories and their respective time periods of emergence, and the brownfield extents were delineated according to the raster images. In the attribute table, new fields and label the brownfield pieces were created as “Y1”, “Y2”, “Y3”, or “Y4” based on their current conditions, as observed from satellite remote sensing images and panoramic views (Figure 5).



**Figure 5.** Input results for the raster image files.

## 5. Discussions

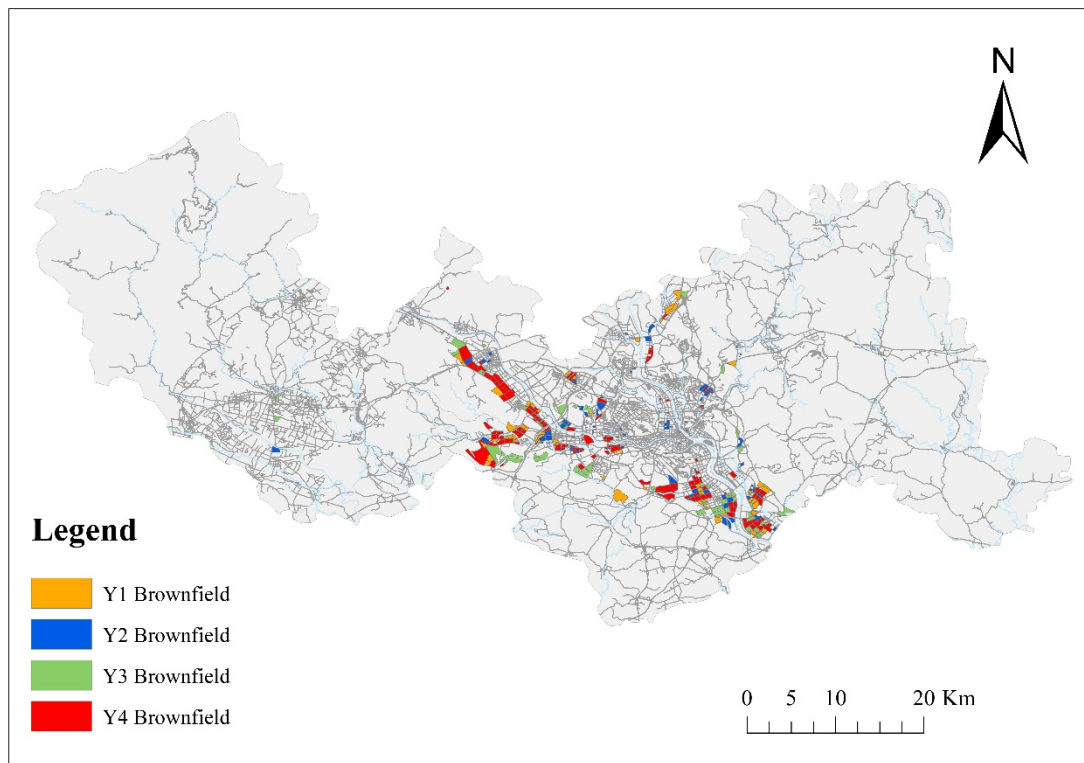
This section takes brownfield sites in the central urban area of Mianyang City as the research object and conducts a statistical classification analysis from four core dimensions: current status, administrative districts, traffic ring roads, and brownfield size. Through comparative calculations using key quantitative indicators such as density, average area, and area standard deviation, this section systematically clarifies the distribution pattern, scale characteristics, and quantitative proportion rules of brownfield sites within the study area. The section also identifies the differentiated attributes of brownfield sites under different dimensions, pinpoints the key areas and crucial directions for brownfield remediation and reuse, and provides quantitative support and decision-making basis for the subsequent precise governance, scientific planning, and efficient development of brownfield sites.

### 5.1. Statistical Classification Based on Current Status

By conducting a statistical classification of brownfields based on their current status, the present situation and primary utilization modes of brownfield reuse in the central urban area of Mianyang were clarified (Figure 6, Table 2). Through a comparison of density, average area, and area standard deviation, the parcel sizes of various types of brownfields in their current states were determined.

**Table 2.** Current brownfield status.

Category	Total Area (ha)	Area Proportion (%)	Quantity (Piece)	Quantity Proportion (%)	Density (Piece/ha)	Average Area (ha)	Area Standard Deviation (ha)
Y1	1712.29	18.54	121	20.20	0.07	14.15	22.99
Y2	1300.10	14.08	152	25.38	0.12	8.56	12.12
Y3	2120.37	22.96	135	22.54	0.06	15.71	24.56
Y4	4101.18	44.42	191	31.88	0.05	21.47	33.97
Total	9234.83	100	599	100	0.06	15.41	25.92



**Figure 6.** Distribution of current brownfield status.

The spatial distribution and classification-based statistical analysis of brownfield reuse in the central urban area of Mianyang reveal that a diverse pattern of reuse types has emerged locally, with significant differences in scale and spatial characteristics among different types of brownfields. A total of 599 brownfield sites, covering 9234.83 ha, have been identified across the region. These brownfields are dispersed in clusters along major urban transportation arteries. Among them, nearly half (44.42% of the total area) retain their original use as polluting enterprises, exhibiting extreme variability in parcel size. This represents the predominant form of brownfield utilization in Mianyang at present. Brownfields repurposed into urban public spaces such as residential and commercial areas account for 25.38% of the total, with the highest development density among the four categories. However, they have an average area of only 8.56 ha and minimal scale fluctuation, reflecting fragmented, small-parcel renewal. Brownfields transformed into green spaces such as parks are fewer in number and have lower development density, but they have an average parcel size of 15.71 ha, indicating large-scale development characteristics. Unutilized idle brownfields account for 18.54% of the total area, with an average size of 14.15 ha and moderate scale, offering substantial potential for redevelopment.

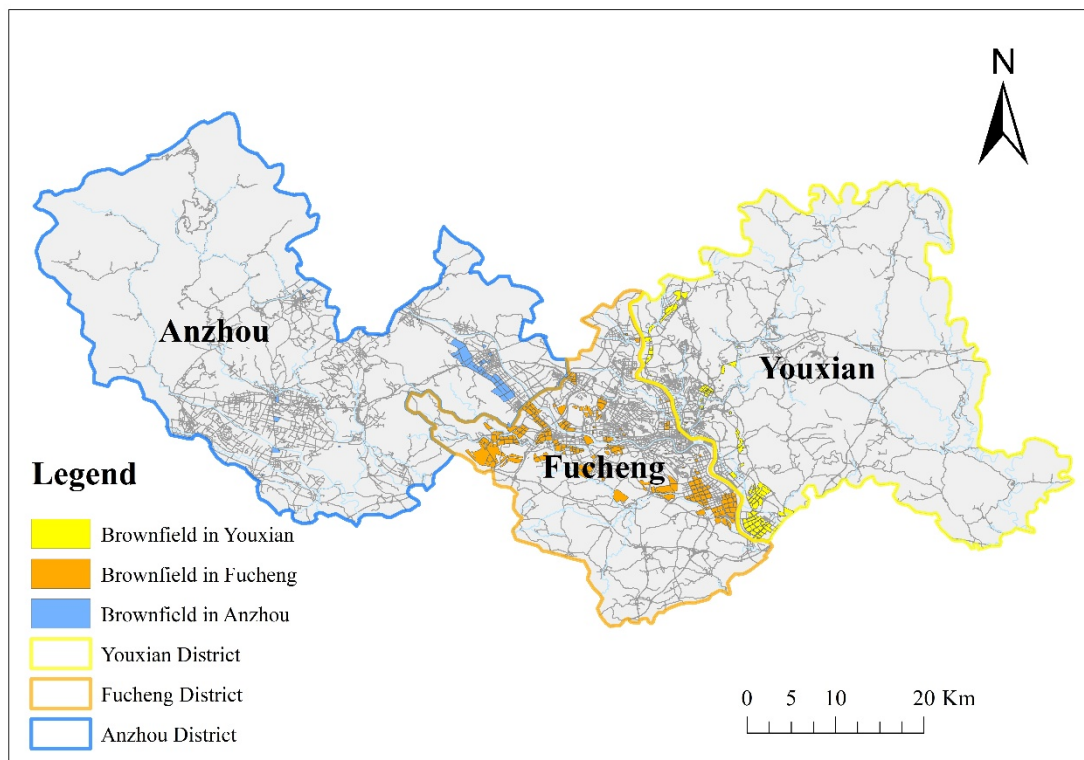
This pattern aligns with the general evolutionary trajectory of brownfields in aging tech-oriented industrial cities. The retention of industrial uses in nearly half of the brownfields is fundamentally a result of Mianyang's status as a traditional industrial city centered on military and technological industries, where industrial path dependency and high costs associated with functional conversion of industrial land converge. This mirrors characteristics observed during the mid-stage transformation of later-developing industrial cities in Europe. The fragmented development of commercial and residential brownfields reflects the market-driven logic of low-cost and high-return brownfield redevelopment. Smaller brownfield pieces have lower remediation costs and higher returns from commercial and residential development, making them more likely to be prioritized for redevelopment—a common feature of brownfield redevelopment during rapid global urbanization. The large-scale development of green-space brownfields meets the scale requirements for effective ecological service delivery, consistent with findings from international research, which indicate that contiguous development is essential for fully realizing the ecological and recreational value of brownfield-to-green-space transformations.

Based on this current situation, future brownfield governance and urban renewal in Mianyang can optimize planning policies in multiple directions: First, it is necessary to align with the requirements of replacing secondary industries with tertiary industries in the territorial spatial planning by systematically phasing out polluting industrial brownfields in the urban core. International best practices of “brownfield remediation + functional development” models should be adopted to attract social capital for remediation and development, driving urban functional upgrades. Simultaneously, moderately sized idle and unutilized brownfields should be prioritized for

inclusion in land reserves and transformed into urban parks and community public service facilities. This approach would not only mitigate potential environmental risks associated with idle brownfields but also address the demand for park city construction and compensate for the shortage of public spaces in older urban areas. Furthermore, to address the issue of fragmented commercial and residential brownfield development, enhanced planning coordination for adjacent pieces is required to ensure unified provision of infrastructure and public services, preventing urban functional fragmentation caused by scattered development and improving the overall livability of urban renewal areas.

### 5.2. Statistical Classification Based on Administrative Districts

By comparing density, average area, and area standard deviation, the parcel sizes of brownfields across different administrative districts were accessed, thereby the districts that require prioritized brownfield remediation efforts were identified (Figure 7, Table 3).



**Figure 7.** Distribution of brownfields in each administrative district.

**Table 3.** Brownfields in each administrative district.

District	Total Area (ha)	Area Proportion (%)	Quantity (Piece)	Quantity Proportion (%)	Density (Piece/ha)	Average Area (ha)	Area Standard Deviation (ha)
Youxian	1999.95	21.65	163	27.21	0.08	12.27	14.39
Fucheng	5765.27	62.43	356	59.93	0.06	16.05	28.66
Anzhou	1572.99	15.92	80	12.86	0.05	19.66	30.52
Total	9234.83	100	599	100	0.06	15.41	25.92

An analysis of the current state of brownfields in the three administrative districts of Mianyang's central urban area, based on spatial distribution and classification statistics, reveals a highly uneven and clustered distribution pattern. This overall trend aligns with the general principles governing spatial expansion and industrial layout in monocentric tech-industrial cities, providing clear planning guidance for implementing differentiated brownfield governance strategies across administrative districts. Currently, over 60% of Mianyang's brownfields are concentrated in Fucheng District, the traditional central urban area, accounting for 62.43% of the total area and 59.93% of the total number. The average parcel size in Fucheng is 16.05 ha, slightly above the citywide average, with a size standard deviation of 28.66, indicating significant variability in parcel scales. This district encompasses both scattered small brownfields resulting from urban renewal in the old city center and contiguous large brownfields located in industrial parks on the urban fringe. This pattern reflects Mianyang's evolutionary trajectory

as an established tech-industrial city, transitioning from sporadic industrial layout in the core area to contiguous development in the suburbs, consistent with the general characteristics of brownfield distribution in monocentric aging industrial cities worldwide.

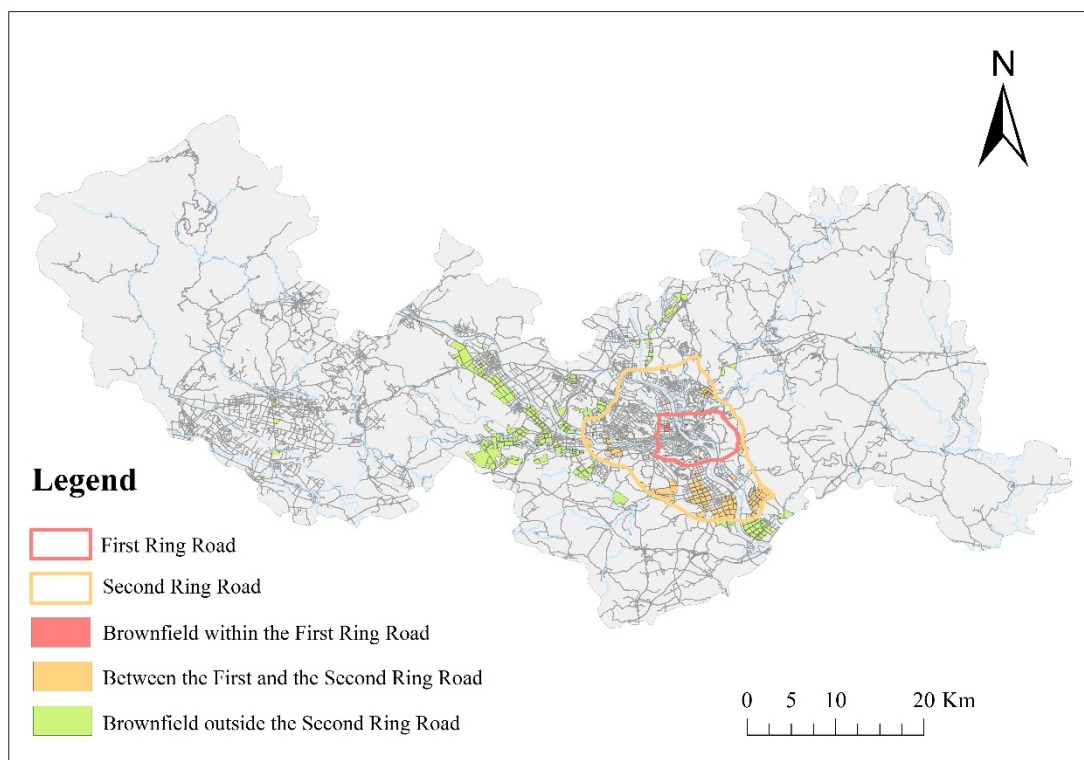
Youxian District accounts for 21.65% of the total brownfield area, with the highest density at 0.08 pieces per ha among the three districts. The average parcel size is only 12.27 ha, with the smallest size standard deviation, indicating a scattered distribution of small pieces. This result aligns with the developmental context of Mianyang's eastward expansion, where formerly suburban township industries have been gradually incorporated into the urban area.

As a newly established peripheral administrative district following the reorganization of counties into districts in recent years, Anzhou District accounts for 15.92% of the total brownfield area, with the lowest density at 0.05 pieces per ha. The average parcel size is 19.66 ha, with the highest size standard deviation of 30.52 among the three districts, indicating a pattern of large-scale, low-density distribution. As the primary recipient of Mianyang's industrial relocation, Anzhou hosts numerous contiguous large industrial brownfields, consistent with the industrial land layout characteristics observed in newly established peripheral administrative districts in international contexts.

Based on this distribution pattern, Mianyang's future brownfield governance and territorial spatial planning should adopt differentiated zoning strategies: Fucheng District's brownfield governance should serve as the core focus of urban renewal, coordinating the redevelopment of both large and small brownfields. This involves systematically phasing out and upgrading polluted brownfields in the core area while balancing commercial development with the provision of public spaces. Given the scattered small brownfields in Youxian District, planning integration can transform idle brownfields into small public spaces such as pocket parks and community service stations, addressing the shortage of public services in urban fringe areas. For the large contiguous brownfields in Anzhou District, these sites can be proactively included in the city's land reserve system. While managing existing environmental pollution risks, this approach reserves sufficient development space for Mianyang's future industrial upgrading, allowing for advance planning of transformation directions.

### 5.3. Statistical Classification Based on Traffic Ring Roads

By comparing density, average area, and area standard deviation, the parcel sizes of brownfields within each traffic ring road were compared (Figure 8, Table 4).



**Figure 8.** Distribution of brownfields along each traffic ring road.

**Table 4.** Brownfields along each traffic ring road.

Ring Road	Total Area (ha)	Area Proportion (%)	Quantity (Piece)	Quantity Proportion (%)	Density (Piece/ha)	Average Area (ha)	Standard Deviation (ha)
Within the First Ring Road	156.87	1.69	50	8.35	0.32	3.14	6.75
Between the First and Second Ring Roads	2898.61	31.38	207	34.56	0.07	14.00	18.31
Outside the Second Ring Road	6415.63	66.93	342	57.09	0.05	18.33	30.39
Total	9234.83	100	599	100	0.06	15.41	25.92

Brownfield sites in the central urban area of Mianyang are predominantly concentrated outside the Second Ring Road, with only a minimal proportion located within the First Ring Road. The brownfield sites outside the Second Ring Road not only account for a substantial 66.93% of the total area but also constitute 57.09% of the total number. These sites exhibit the distinct characteristics of “low density and large area”, with an average area of 18.33 ha and a density of merely 0.05 sites per ha. This scale and distribution pattern highly align with the spatial layout of the original industrial parks, preserving the typical form of industrial land.

Brownfield sites between the First and Second Ring Roads also represent relatively high proportions in terms of both area (accounting for a notable share) and quantity. These sites have an average area of 14.00 ha and a similarly low density (0.07 sites per ha), with an overall scale leaning towards medium-to large-sized land pieces. This aligns with the transformation potential characteristics of district-level public spaces or industrial-type land.

In contrast, brownfield sites within the First Ring Road are at a low level in terms of both area proportion (1.69%) and quantity proportion (8.35%). These sites are characterized by “relatively high density and small area”. Such brownfield sites are more suitable for old city renewal projects focused on small-scale site updates. Their scale and distribution pattern also closely match the layout requirements for small public spaces such as urban pocket parks and small community parks.

#### 5.4. Statistical Classification Based on Brownfield Size

Currently, there is a lack of a unified standard for the classification of brownfield site areas. Considering that their reuse primarily focuses on residential areas, commercial districts, and park green spaces, this study drawn references from relevant literature on the classification of park green space patch levels, the “Standard for Planning of Urban Green Space” (GB/T 51346-2019) [29] and the “Standard for Urban Residential Area Planning and Design” (GB 50180-2018) [30]. Additionally, this study incorporated findings from existing research [3] and established a classification system for brownfield site areas (Table 5).

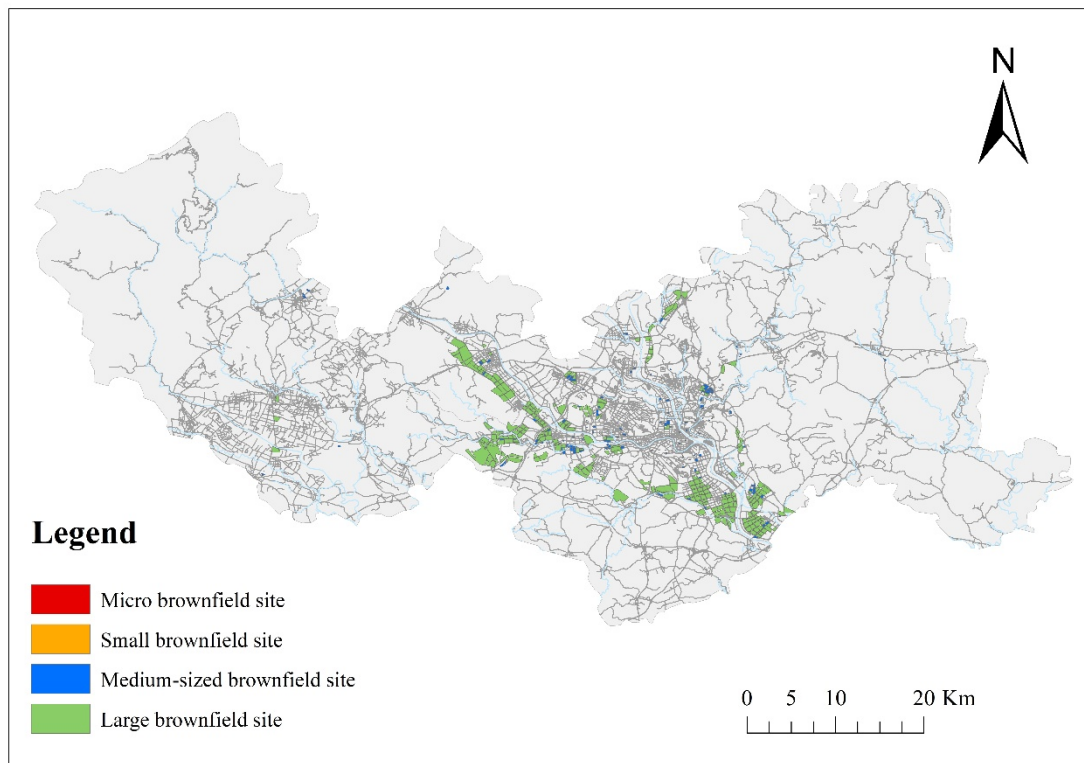
**Table 5.** Brownfields size classification standard.

Brownfield Type	Area Range
Micro brownfield	<0.2 ha
Small brownfield	0.2–1 ha
Medium brownfield	1–10 ha
Large brownfield	>10 ha

By comparing density, average area, and area standard deviation, the typical scale and density levels of various categories of brownfields were compared (Figure 9, Table 6).

**Table 6.** Brownfields classified by size.

Size	Total Area (ha)	Area Proportion (%)	Quantity (Piece)	Quantity Proportion (%)	Density (Piece/ha)	Average Area (ha)	Area Standard Deviation (ha)
Micro brownfield	9.94	0.11	89	14.86	8.95	0.11	0.05
Small brownfield	38.78	0.42	85	14.19	2.19	0.46	0.21
Medium brownfield	745.64	8.07	150	25.04	0.20	4.97	2.78
Large brownfield	8440.47	91.4	275	45.91	0.03	30.69	31.96
Total	9234.83	100	599	100	0.06	15.41	25.92



**Figure 9.** Distribution of brownfields classified by size.

Statistical and spatial analyses of brownfields of varying scales in Mianyang's central urban area reveal an extreme polarization in their size structure, a historical outcome of the long-term spatial arrangement of large-scale military-industrial complexes in the city. This characteristic aligns with the general patterns of brownfield legacy in aging industrial cities, necessitating differentiated planning and governance strategies. In Mianyang's central urban area, large brownfields contribute over 91.4% of the total brownfield area and account for 45.91% of the total number, with an average parcel size of 30.69 ha. In contrast, micro-, small-, and medium-sized brownfields collectively account for less than 9% of the total area, demonstrating a stark disparity in scale hierarchy. This structure is deeply rooted in Mianyang's developmental history as a core military-industrial and technological city. As the city underwent industrial upgrading, these sites gradually transformed into brownfields, ultimately forming a structure dominated by large-scale brownfields.

This structure presents both strategic potential for large-scale contiguous development and significant governance challenges: compared to smaller brownfield pieces, large-scale brownfields entail higher pollution remediation costs, greater difficulties in property rights coordination, and longer development cycles. Without top-level coordination, they are prone to long-term idleness or fragmented development, wasting precious urban space resources. In contrast, while micro- and small-sized brownfields collectively account for a minimal proportion of the total area, their density far exceeds that of large brownfields. Micro-brownfields reach a density of 8.95 pieces per ha, and small brownfields 2.19 pieces per ha, aligning with the "urban acupuncture" renewal philosophy advocated in contemporary international stock renewal practices. These scattered small brownfields are ideally suited to precisely fill gaps in public space provision in older urban areas. Specifically, micro-brownfields are suitable for point-based facilities such as pocket parks and convenience service points, while small brownfields can be transformed into community parks and neighborhood commercial outlets to meet residents' daily service needs.

Medium-sized brownfields, with a density of 0.2 pieces per ha and an average area of nearly 5 ha, accommodate composite functions such as community parks, residential area amenities, and regional commerce, aligning with the construction requirements of 15-min living circles. Given this size-based differentiation, Mianyang's future brownfield governance should adopt a classification-based planning strategy: for dominant large brownfields, government-level coordination is essential to integrate them into key renewal units for holistic planning.

For scattered micro-, small-, and medium-sized brownfields, flexible micro-renewal policies should be implemented, encouraging participation from sub-district offices, communities, and small-scale social capital in their transformation. These small brownfields should be converted into public spaces serving nearby residents, effectively enhancing the livability of older urban areas with minimal investment.

### 5.5. Methodological Implications

This study establishes a multi-source data-driven framework for brownfield identification and database construction, which addresses the limitations of traditional single-source data methods and provides a replicable methodological paradigm for Third Line Construction cities. The core methodological innovation lies in the hierarchical integration of planning data, POI data, satellite imagery and industrial statistics, combined with cross-year POI superimposition-deduplication, coordinate reverse geocoding and ArcGIS-based polygon delineation. This approach realizes standardized binding of brownfield attribute and spatial data, effectively compensating for the low precision of planning data, the lack of attribute information of remote sensing data and the timeliness lag of statistical data.

In this methodological framework, the selected data sources are common in urban planning research, and the analysis relies on mainstream GIS software and basic data processing tools, with a standardized operation process that can be flexibly adjusted according to the data availability of different study areas. Meanwhile, it has clear application boundaries: the framework is most applicable to industrial heritage cities with clustered industrial land and fragmented land rights; for regions with low POI data coverage, on-site investigation should be supplemented to avoid identification omissions or misjudgments. Therefore, the methodology features high accessibility and replicability.

## 6. Conclusions

This study takes the central urban area of Mianyang, a typical Third Line Construction city, as the research object, constructs a brownfield identification framework with POI data as the core supplementary source, and establishes a comprehensive brownfield database using ArcGIS technology. The research identifies 599 brownfield plots with a total area of 9234.83 ha, covering three types including industrial abandoned lands, landfill sites, and abandoned transportation facilities. Statistical analysis from multiple dimensions reveals that brownfields in the study area are predominantly distributed in Fucheng District and outside the Second Ring Road, with large brownfields accounting for 91.4% of the total area; functionally, most are still occupied by polluting enterprises, while others are reused as residential areas, commercial spaces, or green spaces, presenting distinct scale characteristics and functional adaptation directions corresponding to their sizes and locations. When applying this technical framework and research methodology, it is essential to focus on organizing and screening POI data for the target city, as well as conducting coordinate back-checking of the POI data to ensure its authenticity.

The research methods and technical framework developed in this study can be applied for brownfield identification and database construction in similar regions. By integrating POI data, planning data, statistical data, and satellite imagery, the study effectively addresses the limitations of traditional brownfield identification methods such as difficulty in large-scale investigation, imprecise location confirmation, and lack of contamination information. The established classification system for brownfield sizes and the multi-dimensional statistical analysis framework provide a standardized research paradigm for brownfield management in other Third Line Construction cities or industrial heritage-rich regions, offering technical support for precise urban renewal planning and ecological restoration decision-making.

Despite the findings, this study still has some limitations. On the one hand, the identification of brownfield contamination status relies primarily on existing enterprise information and literature records, lacking on-site sampling and detection data. On the other hand, the database does not yet incorporate dynamic update mechanisms for brownfield reuse processes. Future research may strengthen field surveys to supplement pollution type and concentration data, improving the accuracy of risk assessment; establish a dynamic monitoring system for brownfield reuse by integrating real-time remote sensing data and urban construction information, realizing dynamic management of the database. Additionally, further exploration can be conducted on the optimal reuse models for different types and scales of brownfields combined with ecological, economic, and social benefit evaluations, providing more targeted guidance for the sustainable reuse of brownfields.

## Author Contributions

D.D.: Funding acquisition, Investigation, Methodology, Project administration, Visualization, Writing—original draft, Writing—review & editing; H.Z.: Data curation, Formal analysis, Investigation, Software, Validation, Visualization, Writing—original draft; Y.C.: Resources, Supervision, Writing—original draft, Writing—review & editing; D.W.: Writing—review & editing; S.S.: Writing—review & editing. All authors have read and agreed to the published version of the manuscript.

## Funding

This work was supported by the Sichuan “Two Bombs and One Satellite” Culture Research Center [2025ZD003], Sichuan Revolution Cultural Tourism Research Center [HSWL25C06], and the Luzhou Cultural Construction Research Center [WH202506].

## Institutional Review Board Statement

Not applicable.

## Informed Consent Statement

Not applicable.

## Data Availability Statement

Data will be provided by the authors on reasonable request.

## Conflicts of Interest

The authors declare no conflict of interest.

## Use of AI and AI-Assisted Technologies

During the preparation of this work the authors used ERNIE Bot 4.5 Turbo, Doubao, and the thesis polishing tool of AIS to improve English readability. After using the tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the published article.

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