A VÁROSKÖRNYÉKI ZÖLD-INFRASTRUKTÚRA MORFOLÓGIAI TÉRBELI MINTÁZATA

Esettanulmány Zhengzhou városáról, Kínában

MORPHOLOGICAL SPATIAL PATTERN OF PERI-URBAN GREEN INFRASTRUCTURE

A case study of Zhengzhou City, China

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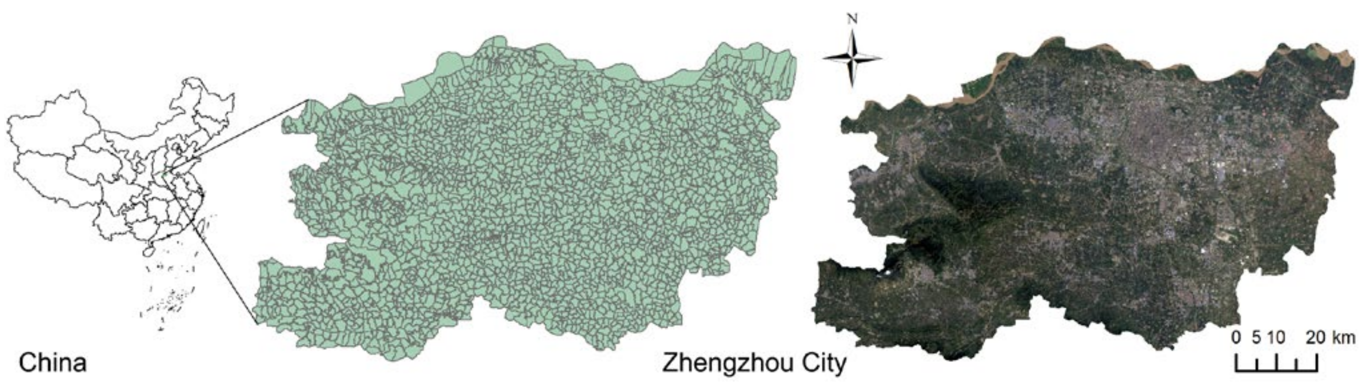

Figure 1: Location, administrative boundaries, and remote sensing image of Zhengzhou

ABSZTRAKT

A városkörnyéki zöldinfrastruktúra (PUGI) a városi problémák kezelésének egyik eszköze. A tanulmány célja a városkörnyéki területek (PUA) azonosítása a Jenks-féle természetes törések módszerével, valamint a PUGI morfológiai térbeli mintázatainak elemzése. A tanulmányból kiderül, hogy a peri-urbán területek többsége a városi régiók peremén található, kisebb részük pedig a vidéki hátországban. A PUA-kon belül a PUGI a terület több mint felét foglalja el, a félig természetes városkörnyéki zöldinfrastruktúra domináns, míg a természetes zöldinfrastruktúra elsősorban összekötő szerepet tölt be. Ezek az eredmények kiegészítik a PUGI morfológiai jellemzőinek elméleti megértését, és a PUGI optimalizálásához nyújtanak segítséget a tervezők számára.

Kulcsszavak: városkörnyéki zöldinfrastruktúra, városkörnyéki területek, morfológiai térbeli mintázatok elemzése, földhasználat ⦿

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ABSTRACT

Peri-Urban Green Infrastructure (PUGI) is one of the tools for addressing urban issues. This study aims to identify Peri-Urban Areas (PUAs) using the Jenks natural breaks method and to analyze the morphological spatial patterns of PUGI. The study reveals that most PUAs are situated on the outskirts of urban regions, with a smaller portion located within rural hinterlands. PUGI occupies over half of the land within PUAs, with semi-natural PUGI holding a dominant position, while natural GI primarily serves as a connector. These findings complement theoretical understanding of PUGI's morphological characteristics and provide insights for planners to optimize PUGI.

Keywords: peri-urban green infrastructure, peri-urban areas, morphological spatial pattern analysis, land use

INTRODUCTION

Under the influence of global urbanization, peri-urban areas (PUAs) are emerging in an increasing number of countries, and can be found in many large cities in China. PUAs are typically defined by their characteristics [1, 2]. Geographically, they constitute a transitional zone between urban and rural areas [2]. Functionally, they encompass urban and rural domains [3]. Demographically, PUAs tend to have population densities higher than rural areas but lower than urban areas [4]. Previous research on PUAs has primarily focused on ecological environment, spatial morphology, and land use. Since the extent of PUAs often exceeds administrative boundaries [5], the spatial identification of PUAs is a prerequisite for studying them.

In recent years, green infrastructure (GI) has gained favor among policymakers and urban planners, becoming one of the tools for addressing urban challenges. This study defines GI as "a strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services" [6]. China's efforts in building GI are primarily reflected in urban green spaces, sponge cities, ecological corridors, and ecological agriculture. According to the 2019 Third National Land Survey of China, GI accounts for 78.83% of the country's land area. However, urban green spaces, which are the main type of GI in urban areas, only cover 0.35% of China's total land area [7]. A significant amount of GI still exists in peri-urban and rural areas.

However, due to insufficient infrastructure or improper planning, the Peri-Urban Green Infrastructure (PUGI) is susceptible to adverse impacts [8]. Compared to urban areas, PUAs have more available space for GI planning. Therefore, it is necessary to identify and conduct spatial analysis of PUGI. Previous research has predominantly focused on urban GI, with studies on PUGI being relatively scarce. There remains a gap in quantitative studies on PUGI.

Based on the aforementioned research background, this study aims to identify specific PUAs and quantitatively analyze the types and morphological characteristics of PUGI. Through a case study of Zhengzhou, China, this research hopes to provide insights for future studies on the identification and evaluation of PUGI.

MATERIALS AND METHODS

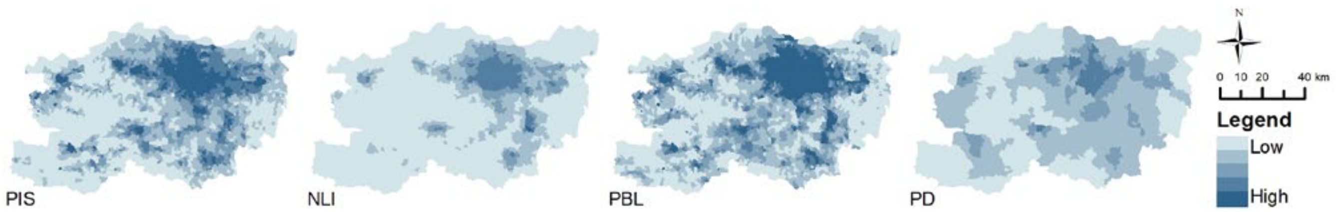
Study area

Zhengzhou, located in the central region of China, is a significant provincial capital covering an area of 7565 km². The topography of Zhengzhou generally trends from higher elevations in the southwest to lower elevations in the northeast, and the region experiences a temperate continental monsoon climate. As of the end of 2020, the permanent resident population of Zhengzhou totaled 12.6 million, with an urbanization rate of 78.4% [9]. As research units, this study utilized the smallest administrative boundaries in Zhengzhou city, namely villages and neighborhoods, totaling 2461 units (Figure 1).

Data

This study employed multiple data sources. Impervious surface data comes from the 2020 Global 30m Resolution Impervious Surface Dataset [10]. Impervious surfaces refer to surfaces that prevent water from penetrating into

Indicator	Description	Weight
Proportion of impervious surface (PIS)	The proportion of impervious surface area to the total area of each unit.	0.1460
Nighttime light intensity (NLI)	The mean value of the nighttime light intensity within each unit.	0.3171
Proportion of built-up land (PBL)	The proportion of built-up land to the total area of each unit.	0.1244
Population density (PD)	The population within each unit divided by its area.	0.4125



the ground. They can be used to characterize the extent of human activity and economic development. Land use/land cover data (30 m × 30 m) encompassed five land types: agricultural land, forest land, grassland, water surface, and built-up land (including urban land use, rural residential areas, and other constructed land) [11]. Nighttime light data can reflect the economic level of different regions and originates from an extended time series (2000–2018) of global NPP-VIIRS-like nighttime light data, with a spatial resolution of 500 meters [12]. Population data is sourced from China's seventh national population census [13]. The administrative boundary data is obtained from the National Platform for Common Geospatial Information Services.

Identification of PUAs

Considering the characteristics of PUAs and drawing upon existing research, this study selected four indicators to identify PUAs (Table 1). The study is based on the assumption that larger values of these indicators indicate more pronounced urban features, while smaller values suggest more pronounced rural characteristics. PUAs are characterized by indicator values that lie between urban and rural areas. The study standardized the indicator value using the range method.

The 'Zonal Statistics' tool in ArcGIS 10.8 was employed to calculate these indicator values by unit (Figure 2). Next, we used the entropy weight method [14] to determine the objective weights of each indicator (Table 1), and calculated the composite indicator values for each unit (Figure 3). The formula is as follows:

$$C = \sum_{i=1}^{n} w_i x_i \qquad (1)$$

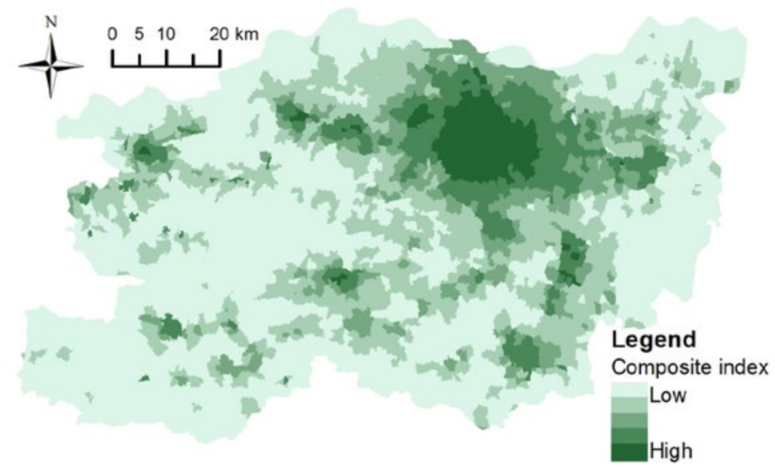
Where C is the value of the composite index, w_i is the weight of the ith indicator, x_i is the standardized value of the ith indicator, and n is the total number of indicators [15].

Finally, the Jenks natural breaks method is used to categorize these units into three classes based on their composite index values, which can be achieved using ArcGIS 10.8. This method determines thresholds based on the inherent characteristics of the data to achieve a rational classification [16]. The category with composite index values falling in the middle range is defined as comprising PUAs.

Morphological spatial pattern analysis (MSPA)

Based on the definition of GI and the land use/land cover data, we consider agricultural land, forest land, grassland, and water surface as GI in this study. We categorize PUGI into two types, based on the degree of naturalness. The first type is natural PUGI, which includes natural forests, natural grasslands, and natural water surfaces. The formation and development of natural PUGI have experienced minimal human interference. The second type is semi-natural PUGI, which is formed and maintained by human

◂◂Table 1: Indicators for identifying PUAs
◂◂Figure 2: The indicators used to identify PUAs in Zhengzhou City
Figure 3: The composite index of each unit in Zhengzhou City
Table 2: Description of some foreground classes in MSPA



MSPA foreground classes	Description
Core	Interior area excluding perimeter
Islet	Disjoint and too small to contain Core
Bridge	Connected to different Core areas

activities. This category includes agricultural land, artificial forests, artificial grasslands, and artificial water surfaces.

Subsequently, we utilized the Guidos Toolbox to conduct MSPA on PUGI. MSPA is employed to detect morphological features of images and categorize them into seven morphological types: Core, Islet, Loop, Bridge, Perforation, Edge, and Branch [17]. Among these classifications, we selected Core, Bridge, and Islet, which correspond to the core areas, corridors, and stepping stones of the GI network, for analysis (Table 2).

Before conducting MSPA, it is necessary to reclassify the land within PUAs in ArcGIS 10.8. The selected land types designated as GI were reclassified as foreground, while built-up land was reclassified as background. Subsequently, the reclassified image was imported into the Guidos Toolbox, where an eight-neighbor analysis method was chosen. The edge width was set to a maximum value of 10, and the transition was set to 1 to obtain distinct bridging areas. The intext was set to 0 to avoid distinguishing between inner and outer landscape types. Once the setup was complete and the final classification results were obtained, the results were subsequently further analyzed according to the classifications of natural and semi-natural GI.

RESULTS AND DISCUSSION

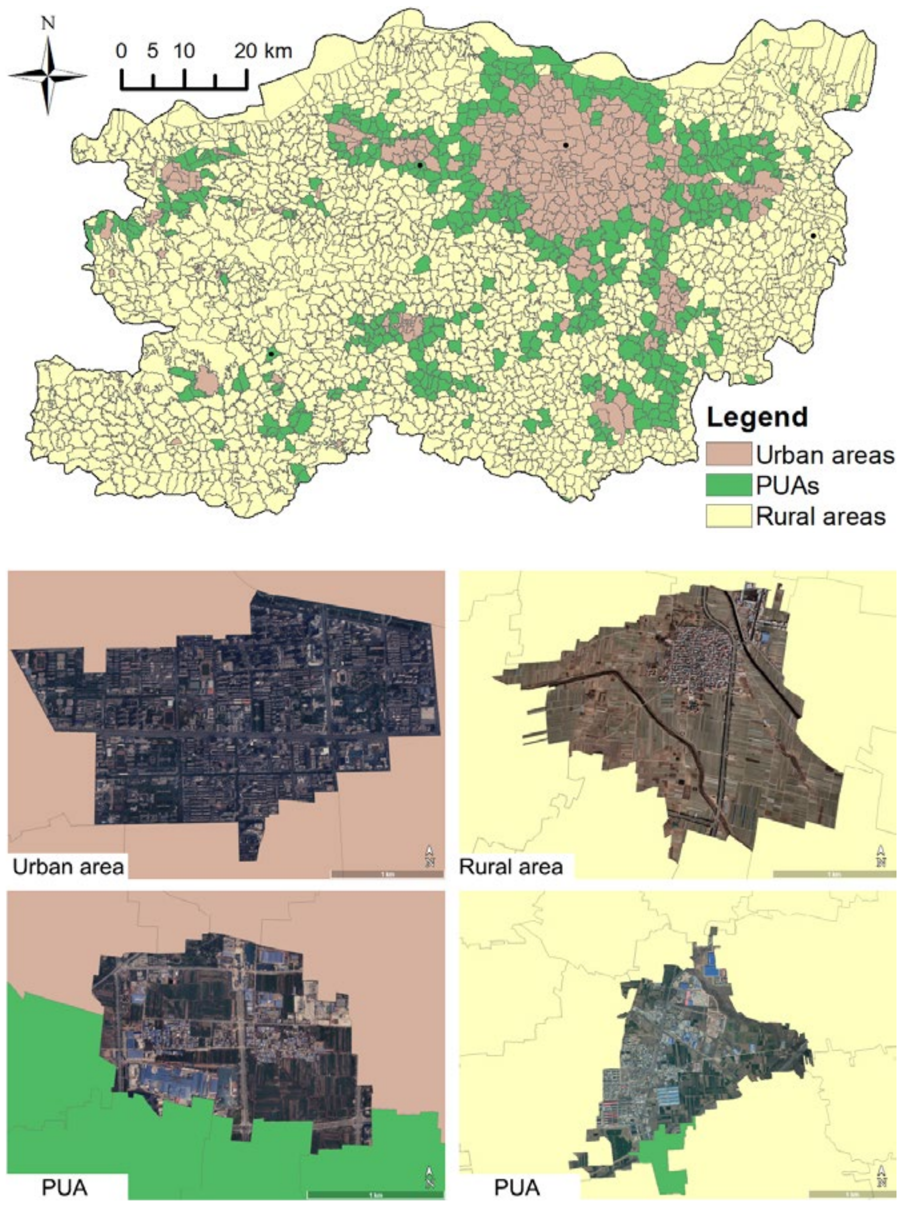
Identification results of PUAs

The classification results indicate that the range of composite indicator values for PUAs is between 0.0927 and 0.2148. PUAs encompassed 468 units, covering an area of 1215.15 km², representing 16.06% of the total area of Zhengzhou. The composite index values for urban areas range from 0.2155 to 0.7192, while those for rural areas range from 0.0005 to 0.0926. Urban areas constituted the smallest portion, encompassing 352 units and occupying an area of 890.96 km². Rural areas comprised 1641 units with a total area of 5458.75 km².

Figure 4 shows that most PUAs are distributed around urban areas and serve as connectors between adjacent urban patches. In addition, some PUAs are scattered throughout rural areas. The spatial distribution of PUAs is also associated with the topography of the study area. Compared to the mountainous regions in the southwest, the flat areas in the northeast contain a higher concentration of PUAs. The geographical distribution of PUAs aligns with previous research [2, 5].

Types and characteristics of PUGI

After extracting PUGI, we found that it covers an area of 660.25 km², accounting for 54.33% of the total land area in PUAs (Table 3). Within PUGI, semi-natural PUGI benefits from extensive agricultural land, occupying as much as 94.66% of the total PUGI area. Similarly high proportions of agricultural land in PUAs have also been demonstrated in other Chinese cities such as Xi'an [18] and Changchun [19], as well as in Western cities like Rome and Fiumicino [20]. Besides agricultural land, forest land has the largest area in the semi-natural PUGI, with grassland having



the smallest area of coverage. Natural PUGI covers only 35.26 km², with the largest area being water surfaces and the smallest area being forest land.

In terms of categories within PUGI, semi-natural forest land far exceeds natural forest land in area. Most of these semi-natural forests are adjacent to urban areas. A significant portion consists of parks converted from natural forests, providing recreational and cultural services. The remaining smaller portion consists of artificial green spaces created from other types of land. Natural forest land is primarily located in areas adjacent to rural regions. The proportion of natural and semi-natural grasslands is similar. Regarding water surfaces, natural water surfaces slightly outnumber semi-natural ones (Figure 5).

Morphological spatial pattern of PUGI

As shown in Table 4, the Core area is consistently the largest across all PUGI types, with the Core area of agricultural land far surpassing that of other land types, indicating the paramount importance of agricultural land within PUGI. This viewpoint has also been corroborated in numerous studies [21, 22]. Agricultural land also exhibits

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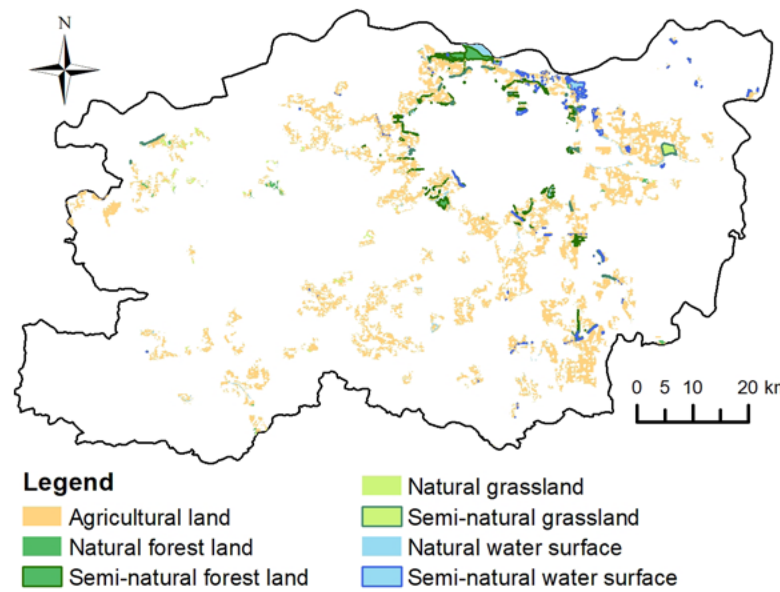
◂◂**Figure 4:** Identification results of PUAs and remote sensing maps of case units from Google Earth
Table 3: The area of each category of PUGI
Figure 5: The distribution of each type of PUGI
Table 4: Areas of different morphological spatial patterns of PUGI

Category	Agricultural land (km²)	Forest land (km²)	Grassland (km²)	Water surface (km²)
Natural GI	–	5.30	8.47	21.49
Semi-natural GI	573.36	25.35	8.87	17.41



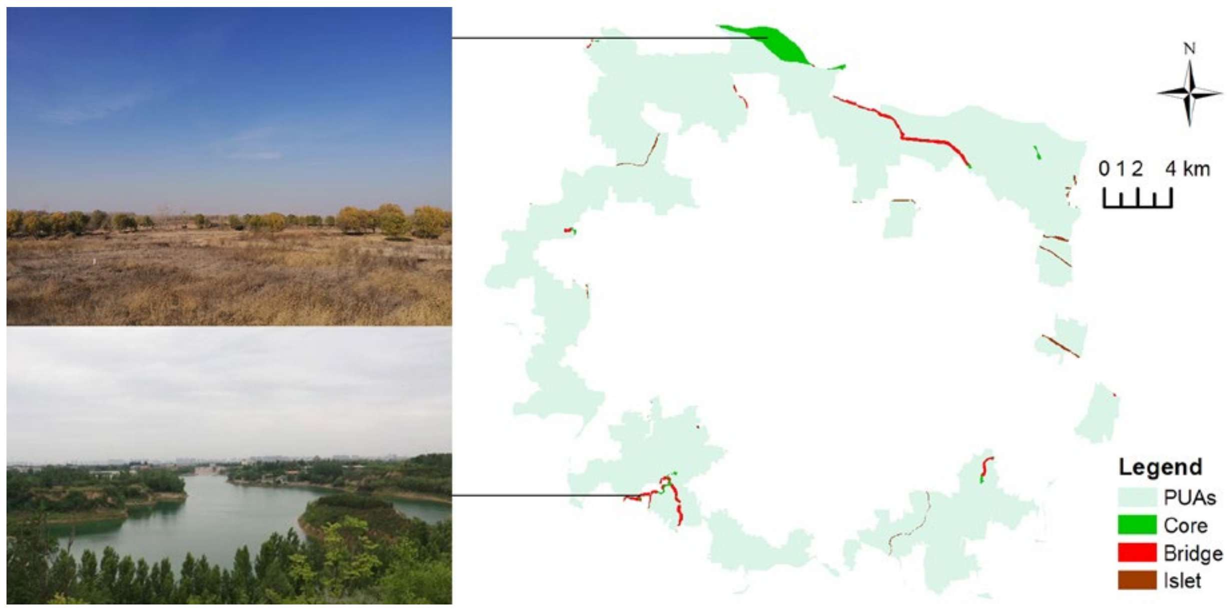
Morphological spatial pattern	Core (km²)	Bridge (km²)	Islet (km²)
Agricultural land	273.87	67.27	4.32
Forest land	11.97	2.48	5.23
Grassland	4.84	2.53	2.79
Water surface	11.58	5.31	7.49
Natural PUGI	8.45	7.71	4.12
Semi-natural PUGI	22.00	3.43	6.91

the largest Bridge area, with relatively few Islets, reflecting a high degree of connectivity among agricultural land patches. The Core area of forest land is second only to that of agricultural land. There are relatively few Bridges and many Islets within the forest land, indicating a low degree of connectivity between it and other Cores. The proportions of Cores, Bridges, and Islets in grassland are relatively similar. As for water surfaces, the area of Islets is the largest among all categories in PUGI.

Next, we conducted MSPA on both natural PUGI and semi-natural PUGI, and used the central urban area as an illustrative example (Figures 6, 7). The results indicate that semi-natural PUGI has more Cores and Islets than natural PUGI but fewer Bridges. This phenomenon suggests that semi-natural PUGI dominates within PUAs, while natural PUGI primarily serves a connecting role (Table 4).

CONCLUSIONS

This study quantitatively delineated PUAs and extracted PUGI for MSPA. The findings indicate that in Zhengzhou, most PUAs are located on the urban periphery, while a



smaller portion are situated in the rural hinterland. PUGI encompasses over half of the land within PUAs. Semi-natural PUGI, primarily consisting of agricultural land, significantly exceeds natural PUGI in area. In the PUAs, semi-natural PUGI predominantly takes the form of Cores, playing a dominant role, while natural PUGI primarily serves a connective function through Bridges.

This study offers a straightforward and efficient method for identifying PUAs, which could be readily replicated in other regions. Moreover, the morphological analysis of PUGI underscores its significance and elucidates the roles played by different types of PUGI. These findings are instrumental in raising awareness among policymakers and planners regarding the importance of PUAs and provide valuable insights for optimizing PUGI. ⦿

Figure 6: MSPA results of natural PUGI in the central urban area of Zhengzhou
Figure 7: MSPA results of semi-natural PUGI in the central urban area of Zhengzhou

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