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# Informal green spaces as a strategic opportunity for urban rewilding in densely built environments

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# Informal green spaces as a strategic opportunity for urban rewilding in densely built environments

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ABSTRACT

Urban rewilding acts as a promising strategy for increasing urban resilience and biodiversity. It is noteworthy that the use of urban rewilding in densely built environments has not been widely explored. These environments, are characterized by scarce land and acute socio-ecological conflicts. In this study, the potential of Informal Green Spaces (IGS) is investigated as strategic rewilding opportunities. To be specific, IGS show potential of spontaneous, low-maintenance sites. Haidian District, Beijing, was selected as a case study. On the basis of a GIS-based Urban Rewilding Opportunity Index (UROI), Urban Rewilding Opportunity Spaces (UROS) were mapped. In 35 plots of the dense built-up area in the Fifth Ring Road, field surveys were carried out. As indicated by the results, a spatial mismatch was found. Specifically, high UROI values were primarily reported in the mountainous areas and large parks. However, the highest abundance of IGS was identified in the relatively low UROIs in the dense urban core, which could take up 88.99% of the total IGS area and 88% of patch counts. Vacant lots were dominated by area of 72%. Besides, structure-associated

and gap spaces were numerous but fragmented. Vegetation analysis indicated a “mid-layer deficiency”. The low shrub cover of 9.14% was identified. Notably, structure-associated IGS showed 100% vine cover. Furthermore, 64% of IGS patches were fully accessible. As revealed by the above-mentioned findings, IGS are not merely residual spaces, their vegetation and accessibility characteristics make them activation-ready. They are a critical, albeit neglected, resource for urban rewilding. These findings open new avenues for urban rewilding in densely built environments, with the potential to support urban regeneration while making cities wilder and more livable.

Keywords：Urban green spaces, Urban rewilding, Opportunity spaces, Informal green spaces, Densely built environment, Urban regeneration

## 1. Introduction

Currently, urban regeneration has been carried out in cities globally. The aim of the regeneration is at addressing aging infrastructure, environmental stress, as well as declining vitality. Urban spaces’ social and ecological structures are significantly changed as natural landscapes have been converted into built-up areas (Rong. Wang et al., 2022). Natural ecological spaces have been narrowed by intensive land development in zones with dense regeneration. As a result, habitat networks are fragmented, and ecosystem services turn out to be diminished (Seto et al., 2012; Theodorou, 2022). It is noteworthy that the above-mentioned spatial reconfiguration has triggered “green deserts” (Ignatieva and Ahrné, 2013). Consequently, residents cannot achieve a sense of well-being and belonging, nor can they engage with the regenerated urban environment (Cox et al., 2017; Zhou, 2022). In response, urban rewilding has emerged as a promising paradigm for restoring ecological

processes in cities (Svenning, 2020). Urban green spaces often serve as important vehicles for urban rewilding. Research has primarily focused on the benefits of formal green spaces, such as public parks and nature reserves (Stanford et al., 2026). However, in the land-scarce, densely built environments created by urban regeneration, informal green spaces (IGS)—spontaneous vegetated areas long dismissed as management blind spots—represent an overlooked yet highly suitable vehicle for rewilding (Feng and Chang, 2017).

Urban rewilding offers a process-oriented alternative to conventional restoration (Perino et al., 2019). It can move beyond the static replication of traditional restoration's historically specific states (Svenning, 2020). Notably, rewilding places a stress on restoring natural processes and self-regulatory capacities through the reduction of human intervention. On that basis, ecosystems can be guided to autonomous succession with wild vitality (Gao, 2020). In urban contexts, urban rewilding places a focus on enhancing biodiversity while seeking land-scarce, densely built environments' harmonious human-nature coexistence (Pettorelli et al., 2019; Sun and Jin, 2026). Moreover, residents' well-being can be enhanced through deep human-nature connection rebuilding (Cox et al., 2017; Threlfall and Kendal, 2018). Urban rewilding opportunity spaces (UROS) refer to urban spaces that are dominated by natural processes or have already involved natural restoration processes, i.e., spaces with protected wilderness or capability in offering suitable ecological conditions for new urban wilderness creation (Jin et al., 2024b). It is globally confirmed that identifying UROS is critical for initiating the urban rewilding process (Jin et al., 2024a), wilderness character and quality mapping (Carver et al., 2013; Radford et al., 2019) and perceived-wilderness mapping in intensely modified landscapes (Müller et al., 2015) locate wilderness persistence at national and regional scales, while urban-scale studies, building on a spatial heterogeneity –

67 biodiversity – human disturbance framework, have identified UROS in metropolises (Jin et al.,
68 2024b; Jin et al., 2024a). In general, an emerging research trend lies in the identification of urban
69 rewilding potential.

70 Conventional planning strategies require large-scale land investment and high maintenance
71 costs. Under land scarcity and fiscal constraints, they become increasingly inadequate (Herman et
72 al., 2018; Rong. Wang et al., 2022). For promoting the development of greenness and city liveliness
73 jointly, new, cost-effective ecological restoration pathways adapting to the complex socio-ecological
74 conditions of built-up areas should be found (Lafortezza and Sanesi, 2019; Ren et al., 2018; Lin and
75 Xiao, 2020). It is in this context that IGS acquire their strategic significance. IGS are widely
76 distributed in densely built environments, including such spaces as abandoned vacant lots,
77 brownfields, railway lines, and utility easements (Rupprecht et al., 2015a; Rupprecht et al., 2015b;
78 Kim et al., 2020). They are generally dismissed as management blind spots or green deserts
79 (Ignatieva and Ahrné, 2013). However, IGS show remarkably high ecological resilience and species
80 richness (Rupprecht et al., 2015a; Hu et al., 2024). As indicated by extensive existing research, IGS
81 can offer urban ecosystem services that can be similar to formal green spaces (e.g., parks, gardens,
82 and reserves) (Stanford et al., 2022) and show significant rewilding potential (Ta et al., 2024). First,
83 for various species, IGS offer critical urban habitats (Rega-Brodsky et al., 2018; Müller et al., 2018).
84 Specifically, native flora and fauna can be involved (Wataru, 2019; Oh et al., 2018; Hwang et al.,
85 2019). Second, residents are more likely to embrace urban nature via IGS (Xiyue Wang, 2017).
86 On that basis, social well-being can be improved (Branas et al., 2018; Wolfe and Mennis, 2012).
87 IGS are a type of green infrastructure that is self-organized and carries out low intervention. They
88 can deliver valuable ecosystem services with minimal financial investment. Besides, IGS can utilize

their unique wild aesthetics to meet the diverse needs of the public for nature experiences. On that basis, IGS significantly promote urban regeneration and jointly produce vitality (Bonthoux and Chollet, 2024; Phillips and Lindquist, 2021). Thus, IGS can be understood as concrete manifestations of novel urban ecosystems and urban wilderness within built environments (Kowarik, 2018): spontaneous, self-sustaining vegetation that supplies biodiversity and nature experiences precisely where formal greening is constrained. This also provides new pathways for urban rewilding in cities around the world confronting similar constraints of land scarcity, fiscal pressure, and shortfalls in formal green space provision.

Understanding the relationship between urban rewilding opportunity spaces (UROS) and informal green spaces (IGS) is critical, particularly because traditionally high rewilding opportunities—such as protected wilderness and large parks—are scarce and costly to create in dense urban cores, whereas IGS are abundant yet largely overlooked. However, previous studies mostly examined rewilding potential and IGS separately, leaving their spatial correspondence and comparative contributions to urban rewilding poorly understood.

With the aim of solving the aforementioned gaps, this study proposes a hypothesis, i.e., IGS are key opportunity spaces of urban rewilding and vitality regeneration in densely built environments. Haidian District, Beijing, was used as a case study. An assessment framework was developed for dense urban cores to solve three key issues:

1) Characterization: What ecological and social characteristics various urban rewilding opportunity spaces exhibit from a regional perspective.

2) Spatial Diagnosis: What patterns IGS display for spatial distribution, vegetation structure, as well as social accessibility in densely built environments.

3) Coupling Mechanisms: The spatial matching relationship of urban rewilding opportunity spaces and IGS, and the extent to which IGS show the potential for urban rewilding.

## 2. Materials and methods

### *2.1. Study Area*

The study area is located in the northwestern part of Haidian District, Beijing. It covers an area of 430.77 km². It has mountains and plains and shows notable urban-rural disparities. In the northwest-southeast axis, it shows a pronounced urbanization gradient (Liu et al., 2025). With a forest coverage rate of 35.56%, the area possesses large-scale natural patches such as parks and green corridors. However, over the past two decades, the built-up area has nearly tripled (Chun; Zhang et al., 2025). As a result, urban ecological spaces have been encroached upon by built-up land. On that basis, the total area decreases gradually, and fragmentation increases.

A macro-identification to micro-empirical strategy was used in this study based on the pronounced urbanization gradient and fragmented ecological spaces of Haidian District. First, UROS were macroscopically identified and mapped across the entire district through GIS-based methods. Next, to achieve in-depth field investigations of IGS, the focus was placed on the densely built environment in the Fifth Ring Road (Figure 1). As a critical boundary of Beijing's urban expansion, the area within the Fifth Ring Road serves as the most pronounced urbanization features of the city. It acts as a high-density cluster of population and buildings and represents the zone with the most acute tension of ecological supply and social demand. The high spatial heterogeneity in population structure, urban fabric, and green space distribution within this area (Wu et al., 2024) offers a highly representative perspective for unraveling the rewilding mechanisms of IGS in

densely built environments.

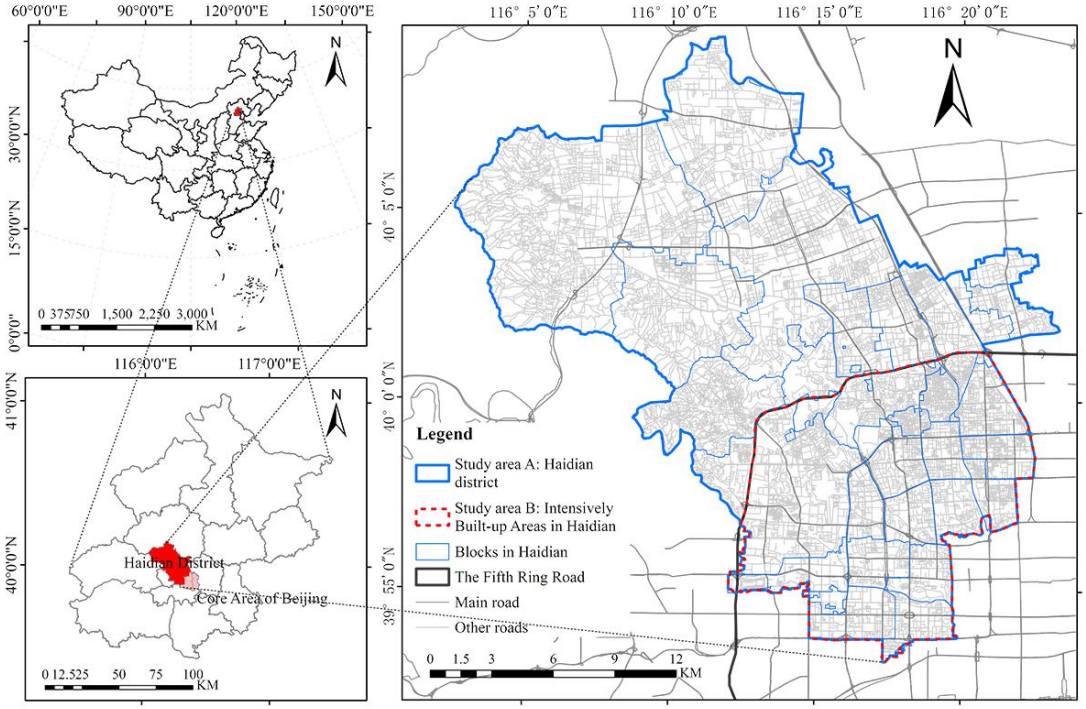



Fig. 1. Haidian district of Beijing, China. The map locates the study area within the densely built environment of Beijing.

*2.2. Study Design*

The overall research design falls in two parts (Figure 2). The first part focuses on mapping UROS in Haidian District. Multi-source open data were integrated, which encompassed land use, topography, population density, buildings, as well as road networks. A recognition system for urban rewilding opportunities was then constructed around three core indicators, i.e., spatial heterogeneity, biodiversity, as well as human disturbance (Jin et al., 2024b). The entropy weight method was employed for calculating the weights of these indicators. We derived the Urban Rewilding Opportunity Index (UROI) by aggregating the weighted indicators. We derived the Urban Rewilding

Opportunity Index (UROI), which refers to the value of urban rewilding opportunities (Jin et al., 2024b), by aggregating the weighted indicators.

Secondly, for characterizing IGS of the densely built environment in the Fifth Ring Road, we carried out a field survey. For designing the survey scheme and establishing sampling plots, we used a grid sampling strategy. In general, data were collected on the basis of on-site measurements. For inaccessible plots, the visual interpretation of street view images was carried out. In three dimensions, i.e., typology, vegetation structure, as well as accessibility, the characteristics of IGS were assessed and analyzed.

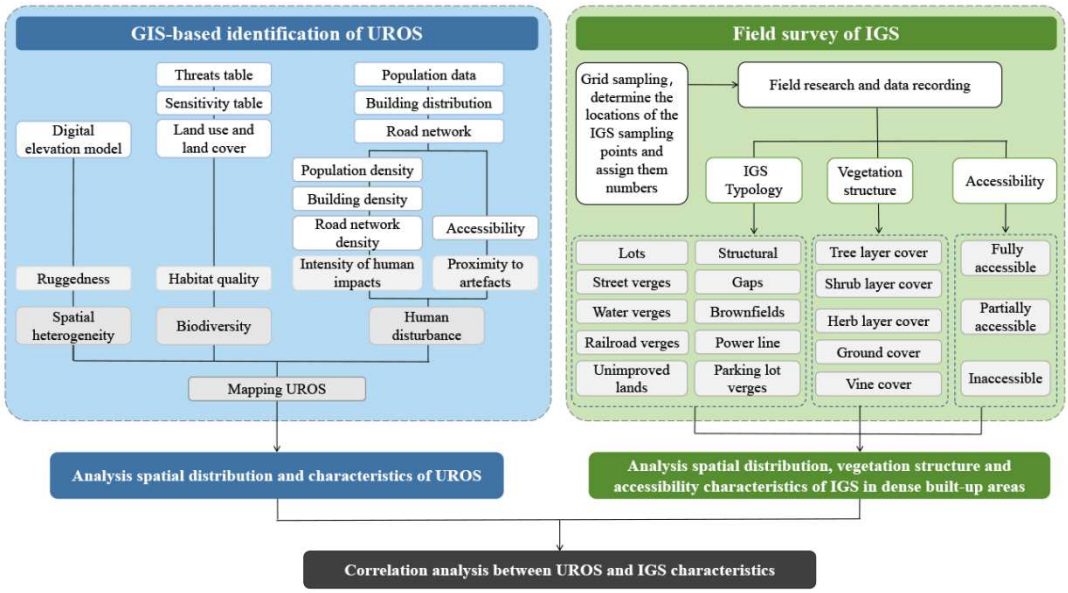



**Fig.2.** Conceptual framework of this study including UROS identification and mapping, as well as the field survey of IGS.

### *2.3. Data Collection*

#### *2.3.1. Identification of UROS*

Three key indicators were selected for identifying urban rewilding opportunity spaces and

generating corresponding spatial maps on the basis of multi-source data (e.g., land use types, population, buildings, and roads) from official open database platforms (Jin et al., 2024a; Jin et al., 2024b). Spatial heterogeneity, biodiversity, as well as human disturbance were involved as the key indicators.

1) Spatial Heterogeneity

The average elevation difference between the respective central cell and its eight surrounding raster cells was obtained by processing a 30-m resolution Digital Elevation Model (DEM) of Haidian District based on QGIS 3.16.3. This derived metric, i.e., Ruggedness, can be employed as a quantitative indicator of spatial heterogeneity (Riley et al., 1999). Accordingly, the terrain's complexity and variability can be reflected.

2) Biodiversity

Biodiversity levels were assessed using the InVEST model's Habitat Quality module (Terrado et al., 2016). The InVEST User Guide was referenced, and the specific environmental characteristics of the study area were incorporated for configuring model parameters (Chen and Li, 2021; Wenyu Wang et al., 2023; Zhu et al., 2024) (Tables 1 and 2). Next, we obtained the spatial distribution of habitat quality in the study area.

3) Human Disturbance

Human disturbance intensity was assessed using four indicators, i.e., building density, road network density, population density, as well as accessibility (Jin et al., 2024a). In ArcGIS 10.8, building density was mapped from building point data. We extracted road centerlines with the ArcScan tool and calculated the total road length per cell to derive road network density. The 30-m resolution population density data were compiled into a full spatial distribution map. We constructed

network-based buffers to evaluate accessibility. Finally, indicators with different resolution data were converted to 500-m resolution data using bilinear interpolation. Next, based on the weighted calculation results, the spatial distribution map of human disturbance intensity was generated.

**Table 1**

The maximum influence distance and weight of threat factors.

| Threat factor | Decay pattern | Maximum impact distance (km) | Weight |
|---|---|---|---|
| Cropland | Linear | 6 | 0.6 |
| Built-up land | Exponential | 8 | 1 |
| Unused land | Linear | 4 | 0.4 |

**Table 2**

Habitat suitability of different land use types and their sensitivity to threat factors.

| Land use type | Habitat | sensitivity | | |
|---|---|---|---|---|
| | | Cropland | Built-up land | Unused land |
| Cropland | 0.4 | 0.1 | 0.6 | 0.3 |
| Forest | 1 | 0.6 | 0.7 | 0.4 |
| Grassland | 0.7 | 0.5 | 0.6 | 0.3 |
| Water | 0.8 | 0.6 | 0.6 | 0.4 |
| Built-up land | 0 | 0 | 0 | 0 |
| Unused land | 0.2 | 0.3 | 0.2 | 0.1 |

Using the Entropy Weight Method (EWM), we calculated the weights of the aforementioned indicators for evaluating urban rewilding opportunity spaces (Shannon and C., 1948; Jin et al., 2024b). Given the significant differences in the magnitude of the indicators, the raw data were first normalized. Subsequently, information entropy was calculated to derive the weights for the respective indicator (Table 3). Lastly, we summed the products of each evaluation indicator and its corresponding weight for computing the UROI at a 500-m resolution.

**Table 3**

Evaluation indicators and weights of UROS.

| Criteria | Elements | Indicators | Weights | Attribute |
|---|---|---|---|---|
| Spatial Heterogeneity | Ruggedness | / | 0.207 324 773 | + |
| Biodiversity | Habitat Quality | / | 0.223 531 143 | + |
| Human Disturbance | Intensity of human impacts | Population density | 0.138 527 766 | - |
| | | Building density | 0.138 897 155 | - |
| | | Road network density | 0.143 050 585 | - |
| | Proximity to artefacts | Accessibility | 0.148 668 578 | + |

*2.3.2 Field survey of IGS*

Concurrently, an in-depth field survey was conducted within the densely built environment inside the Fifth Ring Road. To assess IGS characteristics, we adopted a systematic sampling design, specifically grid sampling (Moreira et al., 2014).

In the study area, we developed a 2×2 km grid using ArcGIS 10.8. The scale can act as an intermediate level between the urban planning block scale and the street-level administrative unit scale. On that basis, IGS differentiation can be precisely obtained in areas that exhibit different construction intensities in the Fifth Ring Road. A total of 35 grid intersections were designated as IGS sampling points, with each plot measuring 50×50 m and assigned identification numbers from 1 to 35. The geographic coordinates of the plots were exported from ArcGIS 10.8. We pinpointed the exact field locations of the respective survey quadrat via the Two Steps Road app. The spatial distribution, vegetation structure, as well as accessibility of IGS were assessed through field surveys. Tape measurements and visual estimation were conducted for collecting data. Only IGS patches that were measured 1 $m^2$ or larger were recorded. Field data were initially recorded on worksheets and subsequently entered into the GIS system for area calculation and distribution analysis. For accuracy, assessments were conducted on-site. For quadrats inaccessible due to construction barriers, private ownership, or safety hazards, visual interpretation using Google Earth and Baidu Street View was employed to supplement information. The assessment content is detailed below.

1) IGS Typology Assessment

This study identified ten types of IGS (Table 5, Figure3). To be specific, lots, street verges, water verges, brownfields, railroad verges, structural, gaps, unimproved lands, parking lot verges, and power line were involved (Rupprecht et al., 2015a; Kim et al., 2018; Kim et al., 2020; Rupprecht et al., 2015b).

**Table 5**

List of IGS types.

| No. | IGS | Examples | | Description |
|---|---|---|---|---|
| 1 | Lots | Vacant lots, abandoned lots | Form | -presently not used for residential or commercial purposes<br>-There may be some abandoned or vacant houses<br>-The space within the boundaries of the land block is empty. |
| | | | Vegetation | -Management of vegetation is irregular, minimal or neglected. |
| | | | Access | -There are either blocking structures such as a fence or boundary stone.<br>-There may be a signboard to prohibit access or unwanted behaviour.<br>-No fences, no signboards. |
| 2 | Street verges | Roadside verges, tree rings, informal trails and footpaths | Form | -within 5 m from street.<br>-In in-between broad cracks in the pavement of sidewalks.<br>-Mainly form the linear structure along the edge of the roads. |
| | | | Vegetation | -Management of vegetation is irregular, minimal or neglected. |
| | | | Access | -There are either blocking structures such as a fence or boundary stone.<br>-No fences, no signboards. |
| 3 | Water verges | Rivers, canals, water reservoir | Form | -Adjacent to rivers, irrigation canals, streams, and wells.<br>-In the cracks on paved embankments. |
| | | | Vegetation | -Most are covered with herbaceous plants, but occasionally |

| | | | | |
|---|---|---|---|---|
| | | edges | | there are shrubs or trees. |
| | | | Access | -There is a closed fence or tall wall with an entry-prohibited signboard.<br>-A high embankment surrounds the site to restrict access.<br>-No blocking structures including sign, fence, or bank. |
| 4 | Brownfields | Landfill, post-use factory grounds, industrial park | Form | -Former use of industrial or commercial purposes but now unused. |
| | | | Vegetation | -Management of vegetation is irregular, minimal or neglected. |
| | | | Access | -There is a closed fence or tall wall with a prohibited signboard. |
| 5 | Railroad verges | Rail tracks, verges, stations | Form | -Space with vegetation adjacent within 10 m of railway tracks. |
| | | | Vegetation | -Vegetation forms linearly along the track or forms communities around a station. |
| | | | Access | -Public access and use mostly restricted. |
| 6 | Structural | Walls, fences, roofs, buildings | Form | -Plants cover artificial structures: walls, fences, bridges, and signboards etc. |
| | | | Vegetation | -Vegetation grows vertically, relying on the structures.<br>-Management of vegetation is irregular or minimal. |
| | | | Access | -There may be differences in public accessibility depending on the type and location of the structure. |

| | | | | |
|---|---|---|---|---|
| | | | Form | -Between buildings, walls, structures, and fences. |
| 7 | Gaps | Gap between walls or fences | Vegetation | -Management of vegetation is irregular, minimal or neglected. |
| | | | Access | -It may be inconvenient to pass because it is not wide enough.<br>-One side may be blocked with structures, but the other side may be open. |
| 8 | Unimproved lands | Undeveloped land plots | Form | -Has the potential for development at any point in time.<br>-No service infrastructure such as telephone, electricity, water pipe, or a road for direct access without structural boundaries.<br>-It is located in periurban areas rather than the central portion of the city, such as the 'Urban Control District'. |
| | | | Vegetation | -Usually no or very infrequent vegetation removal and maintenance. |
| | | | Access | -There is a closed fence or tall wall with an entry-prohibited signboard or no obstacle to entering the space. |
| 9 | Parking lot verges | walls, gaps, surrounding the parking lot | Form | -Sites that utilize vacant lots or unimproved lands for parking purposes. |
| | | | Vegetation | -Vegetation is clustered linearly around the edge of the parking lot, and not by intentional plantings. |
| | | | Access | -There is no obstacle to entering the space.<br>-Some sites are enclosed by fences or a low wall, but the |

| | | | | |
|---|---|---|---|---|
| | | | | entrance is mostly open. |
| | | | Form | -Vegetated corridor under and within 25 m of power lines. |
| 10 | Power line | Power line rights of way | Vegetation | -Composition of the vegetation structure mostly consists of herbaceous plants. |
| | | | Access | -There is a closed fence or tall wall with an entry-prohibited signboard or no obstacle to entering the space. |




**Fig. 3.** Field survey photos of IGS types following its typology.

2) Vegetation Structure Assessment

The vegetation coverage percentages in five distinct vertical layers were obtained for all IGS types (Moreira et al., 2014). To be specific, tree layer cover (vegetation approximately 2 m in height), shrub layer cover (1–2 m in height), herbaceous layer cover (30 cm–1 m in height), ground cover (vegetation below 30 cm), as well as vine cover (plants climbing on structures such as walls and fences) were included as the vertical layers.

Tree canopy cover and herbaceous layer cover are treated as independent metrics, whereas

242 herbaceous layer cover and ground cover are mutually exclusive. The coverage areas for tree canopy
243 and shrub layers were calculated based on their projected areas (i.e., measured from the outermost
244 edge of the canopy projection), while herbaceous layer and ground cover areas were calculated
245 based on actual ground coverage. Vine cover fell into vertical and horizontal components. To be
246 specific, vertical cover area was obtained as the actual coverage length multiplied by a standard
247 width of 0.25 m. Furthermore, horizontal cover area was calculated based on projected area.

248 3) Accessibility Assessment

249 In this study, IGS accessibility fell into three levels (Moreira et al., 2014). The first level was
250 fully accessible. This level shows no entry barriers or only minimal barriers that can be overcome
251 with little effort. The second level was partially accessible. At this level, low fences, "private
252 property" signs, or spatial constraints exist, whereas barriers can still be overcome. The third level
253 was inaccessible. At the inaccessible level, high walls, warning signs, or other substantial barriers
254 require significant effort to overcome. Accessibility barriers (Figure 4) encompass both physical
255 barriers (e.g., fences, walls, chains, or barbed wire) and symbolic barriers (e.g., signs of "No Entry"
256 or "No Children Playing").

257



(a) IGS inaccessible due to height or ditch.

(b) IGS access restricted by physical (fence) and symbolic barriers (sign).

(c)IGS completely fenced off.

258

259 **Fig. 4.** Barriers to IGS accessibility.

260

## 3. Results

### *3.1. Spatial distribution and characteristics of UROS*

Based on multi-source data, the analytical results of the respective influencing factor were calculated and visualized (Figure 5). We multiplied each evaluation indicator by its corresponding weight and summed the products to derive the UROI. Using the Natural Breaks (Jenks) method, the index was classified into five levels: very high (UROI $\geqslant$ 0.750), high (0.624 $\leqslant$ UROI < 0.750), moderate (0.511 $\leqslant$ UROI < 0.624), low (0.418 $\leqslant$ UROI < 0.511), and very low (UROI < 0.418). Figure 6 depicts the spatial distribution map of UROS in Haidian District.

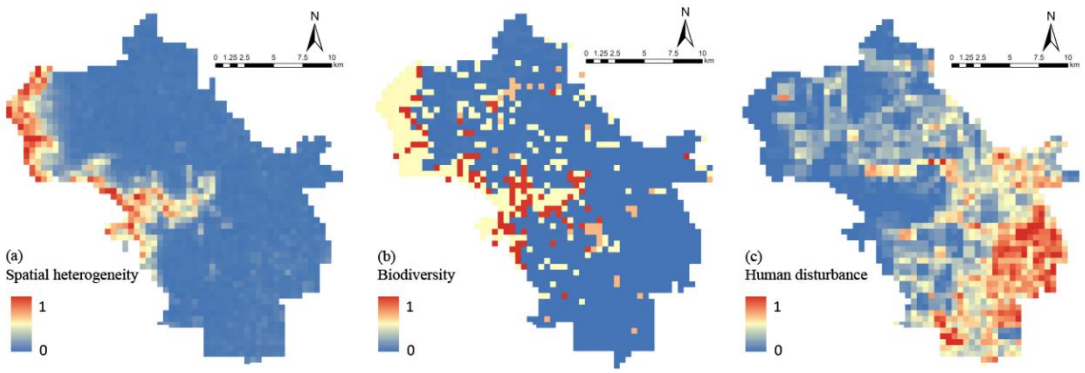



**Fig. 5.** Maps of UROS influencing factors (500m spatial resolution) (a) Spatial heterogeneity: on a scale of 0-1, where 0 represents areas with the lowest ruggedness and 1 represents areas with the highest ruggedness; (b) Biodiversity: on a scale of 0-1, where 0 represents the area with the lowest biodiversity and 1 denotes the area with the highest biodiversity; (c) Human disturbance: on a scale of 0-1, with 0 representing areas with the lowest human disturbance, and 1 indicates areas with the highest human disturbance.

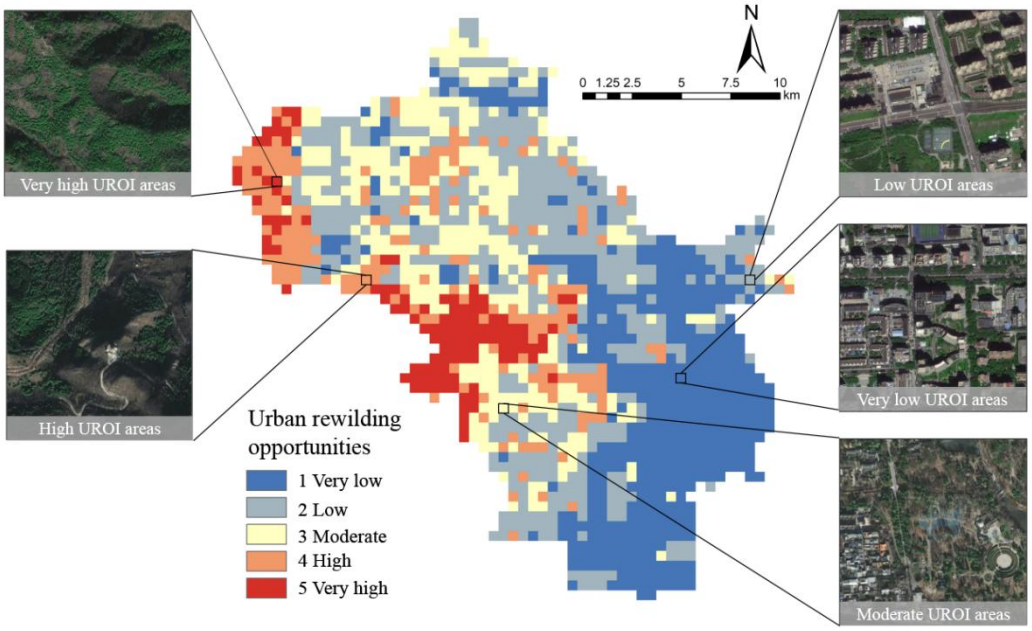



**Fig. 6.** The map of urban rewilding opportunities in Haidian District and examples of UROS. (pictures are from Baidu Maps)

As indicated by the results, the very high UROI areas in Haidian District cover approximately 29.45 km² (7.27%), primarily concentrated in mountainous regions such as Xishan, Xiangshan, and Fenghuangling, as well as park areas like the Baiwang Mountain Forest Park and Jiufeng National Forest Park. Characterized by complex topographic relief and diverse micro-landforms, these areas retain substantial native vegetation and feature complex plant community structures.

Areas with high and moderate UROI values respectively covered 48.63 km² (11.99%) and 122.85 km² (30.31%). These were predominantly natural patches subject to anthropogenic disturbance, mainly comprising semi-artificial, semi-natural coupled systems or rewilding-potential areas formed through natural succession on idle and abandoned lands. Despite their simple community structures, they exhibited high habitat heterogeneity and held potential for biodiversity conservation.

Areas with low and very low UROI values covered 80.62 km² (19.89%) and 123.77 km² (30.54%), respectively. These areas were concentrated in high-density built-up zones in the Fifth Ring Road and the Zhongguancun Science City. Besides, they, characterized by flat terrain, low spatial heterogeneity, intense anthropogenic disturbance, and poor habitat quality.

### *3.2. Spatial distribution, vegetation structure, and accessibility characteristics of IGS in dense built-up areas*

#### *3.2.1. Spatial types and distribution of IGS*

IGS was reported at 62.86% of the sampling sites within the study area, covering a total area of 6,475 m² across 50 patches (Table 6). 'Lots' took up the largest area at 4,662 m² (72%), serving as the core existing stock. Other types' proportions were lower than 10%. These types were listed in descending order of 'water verges' (9.58%), 'railroad verges' (7.31%), 'structural' (4.74%), 'gaps' (3.58%), 'street verges' (1.92%), and 'parking lot verges' (0.88%). As indicated by the above-mentioned findings, idle and abandoned vacant lots constitute the primary carriers of IGS within the Fifth Ring Road, whereas linear corridors and interstitial green spaces, despite their widespread distribution, are limited in scale.

**Table 6**

Number of IGS and its subtypes.

| IGS Type | Count | Area（㎡） | Mean size（㎡） | Proportion/total area(%) | Proportion/Area(%) |
|---|---|---|---|---|---|
| Lots | 9 | 4662 | 518 | 5.33 | 72 |
| Street verges | 7 | 124 | 17.71 | 0.14 | 1.92 |

| | | | | | |
|---|---|---|---|---|---|
| Water verges | 2 | 620 | 310 | 0.71 | 9.58 |
| Brownfields | - | - | - | - | - |
| Railroad verges | 1 | 473 | 473 | 0.54 | 7.31 |
| Structural | 18 | 307 | 17.06 | 0.35 | 4.74 |
| Gaps | 11 | 232 | 21.09 | 0.27 | 3.58 |
| Unimproved lands | - | - | - | - | - |
| Parking lot verges | 2 | 57 | 28.5 | 0.07 | 0.88 |
| Power line | - | - | - | - | - |
| Total | 50 | 6475 | | 7.40 | |

311

312 For patch count, 'structural' was the most numerous with 18 patches, yet it covered a mere 307
313 $m^2$, exhibiting a "small and scattered" distribution. 'Gaps' ranked second with 11 patches and a total
314 area of 232 $m^2$, predominantly occurring in the building-road gaps. 'Water verges', 'parking lot
315 verges', and 'railroad verges' patches were relatively scarce. It is noteworthy that no 'brownfields',
316 'unimproved lands', or 'power line' were identified. The aforementioned findings indicated a
317 distinct pattern. To be specific, large patches were few and concentrated, whereas small patches
318 were numerous and fragmented (Figure 7). Micro-scale IGS (e.g., structure-associated and
319 interstitial types) have been extensively introduced in the interstitial spaces of the built environment.
320 Notably, their individual ecological benefits are limited. Furthermore, their high-density distribution
321 is of great significance in urban micro-ecological regulation and landscape softening.

322

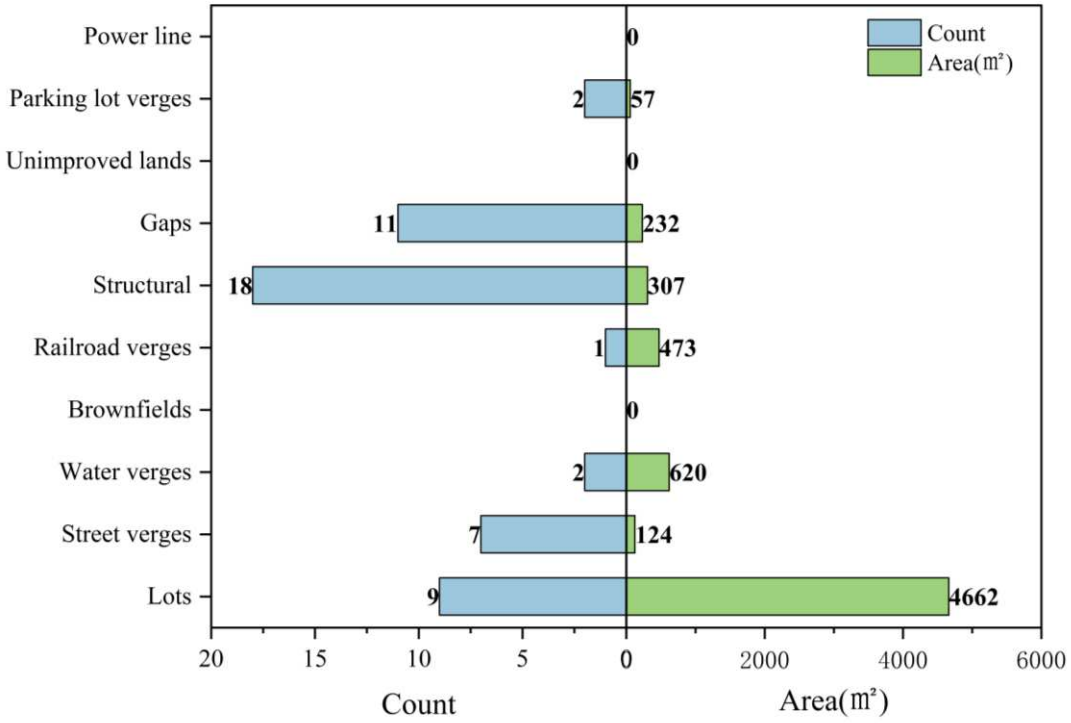



**Fig. 7.** Frequency distribution of IGS patch count and areas across sampling sites.

*3.2.2. Vegetation structure of IGS*

Vegetation communities were present at most sampling sites (Table 7). Structurally, the herbaceous-ground (HG) layer dominated. To be specific, ground cover (54.27%) largely exceeded the herbaceous layer (15.46%). As a result, the core of the HG layer was formed. 'Parking lot verges' consisted entirely of the HG layer and was the only type where the herbaceous layer (61.40%) surpassed ground cover (38.60%), consistent with the scattered distribution of weeds in parking lot gaps. In contrast, 'gaps' had the lowest HG proportion (31.90%); ground cover development was constrained by the high-density shrub layer.

The tree layer was present at a considerable scale. However, it was unevenly distributed. 'Water verges' achieved the highest tree coverage (77.42%). The above-mentioned result could be attributed to water availability and low anthropogenic disturbance. As a result, well-preserved native

trees could be achieved. Due to maintenance control and landscape reconstruction, ‘railroad verges’ had only 23.26% tree coverage, and ‘structural’ had no trees at all.

Vine coverage was merely 4.74% and exclusively distributed in ‘structural’, with no vines found in any other types. Shrub coverage stood at only 9,14%, just above the vine layer, revealing a structural defect of “mid-layer deficiency”. In ‘gaps’, shrubs became the dominant layer (59.48%) due to semi-shaded light conditions and limited space. In other types, shrub coverage primarily ranged from 22% to 30%. Besides, ‘lots’ had a mere 3.26%. Consequently, an extremely low degree of natural colonization could be indicated.

**Table 7**

IGS vegetation structure.

| IGS Type | N* | Tree（%） | Shrub（%） | Herb(%) | Ground(%) | Vine(%) | HG*(%) |
|---|---|---|---|---|---|---|---|
| Lots | 9 | 45.86 | 3.26 | 16.37 | 56.71 | 0 | 73.08 |
| Street verges | 7 | 52.42 | 29.84 | 16.94 | 39.52 | 0 | 56.45 |
| Water verges | 2 | 77.42 | 25.81 | 12.90 | 67.74 | 0 | 80.65 |
| Brownfields | - | - | - | - | - | - | - |
| Railroad verges | 1 | 23.26 | 22.20 | 13.74 | 72.30 | 0 | 86.05 |
| Structural | 18 | 0 | 0 | 0 | 0 | 100 | 0 |
| Gaps | 11 | 50.53 | 59.48 | 15.95 | 15.95 | 0 | 31.90 |
| Unimproved lands | - | - | - | - | - | - | - |
| Parking lot verges | 2 | 0 | 0 | 61.40 | 38.60 | 0 | 100 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Power line | - | - | - | - | - | - | - |
| Total | 50 | 44.94 | 9.14 | 15.46 | 54.27 | 4.74 | 69.73 |

*N = number of IGS as recorded in all 35 sampling sites.

*HG = combined percentage of herb and ground cover.

*3.2.3. Accessibility of IGS*

In general, over 60% of IGS patches were fully accessible. The combined area of fully and partially accessible patches totaled 4,736.5 m², accounting for 72% of the total scale, indicating high potential for open utilization. Inaccessible patches took up 28%. Ownership issues and closed management practices largely constrained these patches (Table 8).

'Parking lot verges', 'railroad verges' and 'street verges' have inaccessible patches. Thus, they were classified as typical high-accessibility IGS. Distributed linearly along public spaces with open ownership and minimal physical barriers, they possessed the strongest public service attributes.

'Lots' exhibited a "binary differentiation" in accessibility. Open vacant lots, typically large and contiguous, were the core stock of accessible IGS. They offered a spatial foundation for rewilding. Under the effects of walls or ownership restrictions, the rest patches became inaccessible.

The poorest accessibility was reported in 'gaps'. To be specific, only 18.18% of patches were fully accessible. As a result, about two-thirds of their area turned out to be unusable. This is largely because they were predominantly located in enclosed or semi-enclosed spaces with restricted public access, such as gaps between building fences and courtyard walls, where physical and ownership barriers were prominent. Only a few interstitial spaces adjacent to streets or public roads were accessible. Consequently, the weakest overall public service attributes were triggered.

We identified a high proportion of fully accessible patches in ‘structural’ (83.33%). Notably, the mentioned patches only covered 1.33% of the total area. In general, public fences with no access barriers showed most small-scale, street-facing vine patches. It is noteworthy that large, continuous vine patches on structures were generally situated in residential compounds or institutional units, facing ownership restrictions.

**Table 8**

IGS accessibility.

| Accessibility | Lots | Street verges | Water verges | Brown-fields | Railroad verges | Struct-ural | Gaps | Unimproved lands | Parking lot verges | Power line | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Total(N) | 9 | 7 | 2 | - | 1 | 18 | 11 | - | 2 | - | 50 |
| Total(㎡) | 4662 | 124 | 620 | - | 473 | 307 | 232 | - | 57 | - | 6475 |
| Yes(N) | 5 | 6 | 1 | - | 1 | 15 | 2 | - | 2 | - | 32 |
| Yes(N%) | 55.56 | 85.71 | 50.00 | - | 100 | 83.33 | 18.18 | - | 100 | - | 64.00 |
| Yes(㎡) | 3130 | 84 | 580 | - | 473 | 86.5 | 62 | - | 57 | - | 4471.5 |
| Partial(N) | 0 | 1 | 0 | - | 0 | 1 | 2 | - | 0 | - | 4 |
| Partial(N%) | 0 | 14.29 | 0 | - | 0 | 5.56 | 18.18 | - | 0 | - | 8.00 |
| Partial(㎡) | 0 | 40 | 0 | - | 0 | 205 | 20 | - | 0 | - | 265 |
| No(N) | 4 | 0 | 1 | - | 0 | 2 | 7 | - | 0 | - | 14 |
| No(N%) | 44.44 | 0 | 50.00 | - | 0 | 11.11 | 63.64 | - | 0 | - | 28.00 |
| No(㎡) | 1532 | 0 | 40 | - | 0 | 15.5 | 151 | - | 0 | - | 1738.5 |

377

378 *3.2.4. Correlation Analysis between UROI and IGS Characteristics*

379 We reported 22 with IGS (Table 9) among the 35 sampling sites surveyed. A distinct inverse
380 gradient relationship was observed between the UROI and both the patch count and total area of
381 IGS (Figure 8). To be specific, larger total IGS scales and higher patch counts were reported in areas
382 with lower UROI values. The total IGS area in very low UROI reached 4,211.75 m². This data took
383 up 65.05% of the total IGS area (6,475 m²), followed by low UROI at 24.72%. For patch count,
384 very low UROI covered 35 patches (70% of the total). On that basis, they could serve as the most
385 densely distributed areas for IGS.

386

387 **Table 9**

388 Summary Statistics of UROI and IGS Distribution in sampling sites.

| **UROI** | **No.** | **Count** | **Area IGS（㎡）** | **Proportion/site(%)** | **Types of IGS** |
|---|---|---|---|---|---|
| High(1) | 27 | 1 | 580 | 23.2 | Water verges |
| subtotal | | 1 | 580 | Water verges:1 | |
| Moderate (1) | 15 | 4 | 82.5 | 3.30 | Street verges, Parking lot verges, Structural(2) |
| subtotal | | 4 | 82.5 | Street verges: 1, Parking lot verges: 1, Structural: 2 | |
| | 1 | 4 | 54.25 | 2.17 | Street verges（3）, Structural |
| | 8 | 2 | 1455 | 58.2 | Lots, Railroad verges |
| Low(6) | 20 | 1 | 2.5 | 0.10 | Structural |

| | | | | | |
|---|---|---|---|---|---|
| | 21 | 1 | 5 | 0.2 | Structural |
| | 26 | 1 | 50 | 2.00 | Street verges |
| | 34 | 1 | 34 | 1.36 | Structural |
| subtotal | | 10 | 1600.75 | Lots: 1, Street verges: 4, Railroad verges: 1, Structural: 4 | |
| | 2 | 3 | 48 | 1.92 | Street verges(2), Gaps |
| | 4 | 6 | 760.25 | 30.41 | Lots(2), Gaps, Structural(3) |
| | 5 | 5 | 525 | 21.00 | Lots, Gaps(3),Structural |
| | 9 | 1 | 4 | 0.16 | Structural |
| | 10 | 1 | 40 | 1.60 | Water verges |
| | 11 | 1 | 7.5 | 0.30 | Structural |
| Very | 14 | 1 | 10 | 0.40 | Structural |
| low(14) | 18 | 5 | 294.5 | 11.78 | Lots(2), Gaps(2), Structural |
| | 23 | 1 | 6 | 0.24 | Structural |
| | 25 | 1 | 1650 | 66.00 | Lots |
| | 30 | 2 | 66 | 2.64 | Gaps(2) |
| | 31 | 5 | 734 | 29.36 | Lots(2), Parking lot verges, Structural(2) |
| | 32 | 2 | 51.5 | 2.06 | Gaps, Structural |
| | 35 | 1 | 15 | 0.6 | Gaps |
| subtotal | | 35 | 4211.75 | Lots: 8, Street verges: 2, Water verges: 1, Gaps: 11, Parking lot verges: 1, Structural: 12 | |

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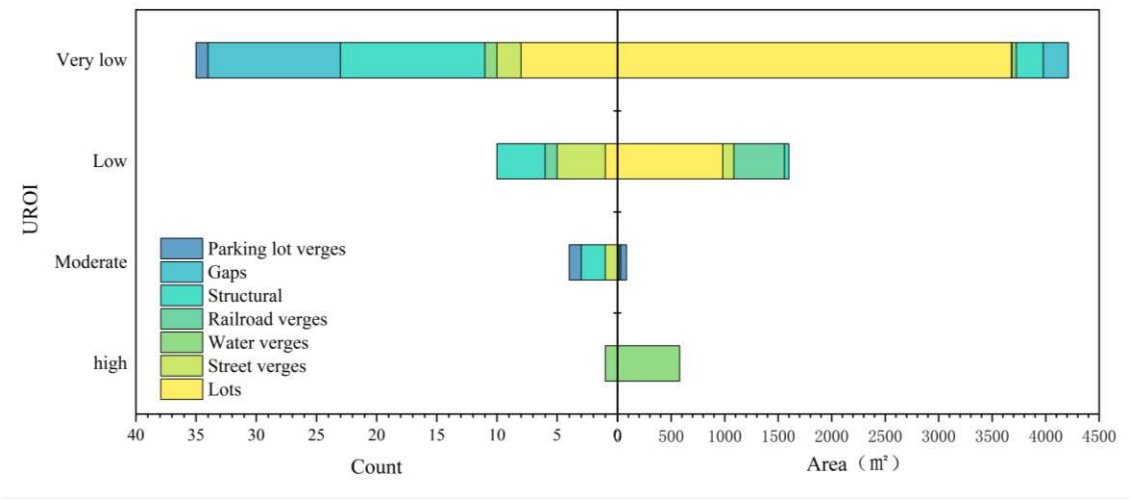



Fig. 8. Frequency distribution of IGS count and area in various types of UROI in sampling sites.

The above inverse pattern arises from different zones' spatial context. In general, higher UROI areas are close to large-scale urban green spaces. As a result, there are scarce surrounding IGS. Besides, they mainly cover large natural types (e.g., water verges). Consequently, a large scale is formed, whereas the quantity is greatly limited. In areas with relatively low UROIs, the types of IGS turn out to be more diverse. Larger patches (e.g., lots and railroad verges) appear with a rise of small micro-patches (e.g., structural and gaps). Thus, area and patch count increase. Notably, the aforementioned areas have substantially elevated rewilding implementation threshold and costs, which can be attributed to constraints (e.g., complex ownership, high surrounding impervious surface ratios, and intense anthropogenic disturbance).

Low UROI areas are the core zones with the richest IGS stock and most diverse types. They act as the spaces with the highest strategic value for urban rewilding. The potential can be corroborated by the areas' vegetation structure and accessibility. For vegetation, 'lots' take up most parts of the area. A tree coverage rate of 45.86% is obtained. Thus, 'lots' offer a foundational canopy

skeleton. ‘Structural’ achieve 100% vine coverage. On that basis, advantageous conditions can be offered for vertical greening. Shrubs dominate ‘gaps’ (59.48%). Accordingly, a naturally dense shrub structure is formed. In this structure, the tree coverage reaches 50.43%. The above result can indicate a sufficient ecological base for activation. For accessibility, large, fully accessible ‘lots’ are contained in low-value areas. Besides, the role of connecting corridors is played by partially accessible ‘gaps’ and ‘structural’ patches. Therefore, urban rewilding can more effectively transition from isolated (embellishments) to systematic networks. Under the above-mentioned high heterogeneity in vegetation structure and accessibility, low rewilding opportunity areas can show immense potential rewilding opportunities.

## 4. Discussion

### *4.1. IGS as key carriers for rewilding in dense built-up areas*

As demonstrated by the present study, IGS are widespread and show great rewilding potential in the densely built-up areas of Haidian District, Beijing, of the Fifth Ring Road. In general, in urban management contexts, the mentioned spaces are considered blind spots or leftover spaces. However, as revealed by our survey, IGS were found at 62.86% of the sampling sites, which could cover an area of 6,475 m². The above finding proves IGS to be crucial ecological patches in highly artificial environments.

The dominance of ‘lots’, which accounted for over three-quarters of the total IGS area, echoes international evidence that vacant and abandoned lots constitute an underexplored ecological and social resource in cities (Anderson and Minor, 2017) and that idle land is a principal carrier of informal urban greenspace (Rupprecht and Byrne, 2014). In general, ‘lots’ are larger in scale with

lower anthropogenic disturbance. Accordingly, complex plant communities can be formed, and wildlife habitats can be provided in the areas.

In terms of microhabitat value, ‘structural’ and ‘gaps’ are small in individual areas. However, they are large in quantity (18 and 11 patches, respectively). Moreover, they are extensively involved in the built environment, mirroring the observation that spontaneous vegetation colonises the narrowest interstices of the built fabric, from building – road gaps to fences and facades (Bonthoux et al., 2019). The above-mentioned spaces underpin urban vertical greening and support micro-biodiversity. It is noteworthy that their unique effect of urban microclimate improvement and green volume increase can be highlighted by the 100% vine coverage in ‘structural’. On that basis, using IGS to achieve interstitial greening and guide natural succession can be the most cost-effective for urban rewilding in central urban areas with unfeasible large-scale demolition and reconstruction.

Accessibility, a dimension rarely included in rewilding assessments, proved favourable for activation. As the findings of this study indicate, 64% of IGS patches are physically fully accessible. However, the public currently perceives these areas as messy, unkempt wastelands. ‘Lots’ exhibited a binary differentiation between large open parcels and walled, ownership-restricted ones, while ‘gaps’, the type with the richest vegetation structure, were the least accessible because they lie predominantly within private or semi-private spaces. This finding adds an equity dimension to rewilding planning: the presence of wild vegetation alone does not guarantee its social value, and access, ownership, and management arrangements shape who can benefit from urban rewilding (Kowarik, 2018; Rupprecht et al., 2015b).

*4.2. The inverse association mechanism between UROI and IGS distribution*

The spatial pattern of UROS reflects a continuum of urban wildness rather than a simple binary

of wild and non-wild land. Very high UROI areas, covering about 7.27% of the district, are concentrated in mountainous and forest-park landscapes that retain complex topography, native vegetation, and species-rich community structures. High and moderate UROI areas, together more than 42% of the district, consist predominantly of semi-natural patches and idle or abandoned lands in which spontaneous succession is already rebuilding habitat heterogeneity. Low and very low UROI areas, which cover roughly half of the district, are the dense built-up zones where wildness survives only as fragmented linear and point-like patches in interstitial spaces. This gradient resonates with the conceptualisation of urban wilderness as a spectrum spanning remnant ecosystems, novel ecosystems, and spontaneously developed communities, each with different supply, demand, and access characteristics (Kowarik, 2018). It is also consistent with evidence that wildness and habitat quality jointly drive the spatial distribution of urban biodiversity (Aznarez et al., 2022). UROS mapping therefore serves a dual function: it identifies where existing wildness should be protected and where natural processes should be restored.

A notable negative link of the UROI and the distribution scale of IGS is identified. Low UROI zones show high-density built-up areas and intense anthropogenic disturbance. These zones exhibit large IGS area and high patch count. Globally, this is consistent with prior studies, in Vienna, the proportion of IGS increases with increasing built-up density (Zoderer et al., 2024). In densely populated areas in cities like Brisbane, Sapporo, or Ichikawa City, IGS at street verges, railways verges, lots, waterside spaces and wild vegetation around technical structures accounts for a considerable proportion (Kim et al., 2020; Rupprecht and Byrne, 2014).

The unique rule of urban ecological succession can be revealed by the above phenomenon. Well-established formal green space systems and strong ecological baselines are found in high

473 UROI zones (e.g., the Western Hills and areas surrounding forest parks). Consequently, “informal”
474 spaces have little room to develop. In low UROI zones, however, intensive development has left
475 numerous idle lands, road edges, as well as building interstices. These idle lands wait for
476 redevelopment.

477 On that basis, the focus of urban rewilding should move beyond suburban areas or large parks
478 with favorable ecological baselines. Central urban areas with low ecological scores and fragmented
479 environments should be emphasized. The greatest marginal ecological benefits can be yielded
480 through rewilding interventions in the above-mentioned areas, thereby responding to calls to treat
481 rewilding as the restoration of ecological dynamics and to integrate wild ecosystems into urban
482 green infrastructure planning (Kowarik et al., 2019).

483 *4.3. The Importance of Vegetation Structure to the Development of Rewilding*

484 Despite their rewilding potential, vegetation structure analysis indicates high structural
485 deficiencies in IGS, primarily characterized by a mid-layer deficiency. This reflects intensive
486 management legacies, site disturbance, and space limitation, and indicates that many patches remain
487 at early successional stages. As revealed by survey data, IGS are dominated by ground cover
488 (54.27%) and the tree layer (44.94%). Notably, shrub coverage is merely 9.14%. The above-
489 mentioned polarized tree-herb structure lacks a shrub layer. It can reduce vertical complexity and
490 ecological stability. Yet the same structure provides the ruderal foundation on which rewilding can
491 build: herb and ground layers dominate where spontaneous colonisation begins (Rupprecht et al.,
492 2015a). Notably, spontaneously developed vegetation, although often dismissed as weeds, delivers
493 measurable ecological functions and constitutes a legitimate basis for urban biodiversity (Bonthoux
494 et al., 2019).

Thus, nature-based interventions should be implemented for future rewilding management. First, the mid-layer should be supplemented by appropriately planting native shrubs in ‘lots’ and ‘street verges’ to establish tree-shrub-herb multi-layered communities (Yu Zhang and Dai, 2022) and enhance ecosystem resilience. Second, it is necessary to prioritize and guide natural succession (Sikorska et al., 2021). It is important to protect and utilize climbing plants for transforming structure-associated and interstitial IGS into urban vertical forests. Moreover, root systems should be prevented from compromising building safety.

*4.4. Implications for the Strategic Development of IGS in Urban Rewilding*

This study redefines the practical meaning of "urban rewilding opportunity" in dense cities. Low UROI values are commonly interpreted as low rewilding potential (Jin et al., 2024b), yet our results show that these areas simultaneously face the highest implementation thresholds—complex ownership, high impervious-surface ratios, and intense disturbance—and possess the richest IGS stock. Urban rewilding in such zones is therefore not the creation of wildness from nothing but the activation of existing spontaneous communities through light-touch management, protection from intensive landscaping, and the relaxation of disturbance regimes, an approach consistent with letting natural processes lead (Lehmann, 2021; Perino et al., 2019). The corollary is a governance warning: converting IGS-rich zones into conventional parks would destroy the spontaneous character that constitutes their rewilding value, so management should privilege protection, minimal intervention, and public access rather than intensive design (Kowarik, 2018).

The inverse gradient between UROI and IGS distribution constitutes the central finding of this study. Two mechanisms explain this pattern. On the supply side, high UROI zones lie close to large formal green spaces and remnant habitats, leaving little room for IGS, and the few that occur are

large natural types such as ‘water verges’. On the stock side, low UROI zones are dominated by idle lots, fragmented interstitial spaces, and disturbed edges, which generate precisely the conditions—unmanaged soil, spontaneous colonisation, and management neglect—under which IGS proliferate (Anderson and Minor, 2017; Rupprecht and Byrne, 2014).

The inverse UROI and IGS distribution carries substantial strategic implications. The low UROI zones that conventional UROS mapping would rank lowest are, on closer inspection, the core zones with the richest and most diverse IGS stock, and their vegetation and accessibility characteristics make them activation-ready. ‘Structural’ patches offer near-complete vine cover for vertical greening, and ‘gaps’ contribute dense shrub structure with appreciable tree cover; in combination, these types supply the multi-layered structural basis on which self-sustaining wildness can be assembled. Moreover, large open ‘lots’ can act as rewilding cores while partially accessible ‘gaps’ and ‘structural’ patches function as connecting corridors, enabling urban rewilding to move from isolated embellishments to systematic networks.

For the global knowledge base, the study offers four contributions. First, it provides empirical evidence from a high-density Chinese mega-city, documenting the typology, vegetation structure, and accessibility of IGS in a context of extreme density, intensive management, and distinctive ownership regimes; previous IGS knowledge has been geographically concentrated in developed countries such as Japan, Australia, and Germany (Rupprecht and Byrne, 2014; Rupprecht et al., 2015a; Kowarik, 2018), and evidence from developing countries remains scarce. Second, methodologically, the study couples macro-scale, multi-source UROS mapping with micro-scale field surveys of IGS, bridging the planning scale and the plot scale; while UROS frameworks have been operationalised at regional and metropolitan scales (Jin et al., 2024b), linking mapped

opportunity to ground-verified activation stock is a step towards operational rewilding planning. Third, conceptually, the proposed inverse UROI and IGS distribution offers a transferable model for where and how rewilding can be implemented in dense built environments, extending the UROS concept and contributing to the emerging urban rewilding agenda (Lehmann, 2021). Fourth, for planning practice, the findings indicate that rewilding need not be confined to peri-urban nature or large parks but can be woven into the urban fabric through the protection and activation of informal green spaces, informing green infrastructure and biodiversity strategies in cities worldwide (Kowarik et al., 2019; McKinney et al., 2018).

### *4.5. Research Limitations*

Limitations of this study are presented below. First, the field survey of IGS was carried out in Autumn (September–November). As a result, the growth dynamics of ephemeral plants in spring may not be captured. Second, for IGS patches that were inaccessible during field surveys, errors may be caused by street view imagery-based interpretation. In subsequent research, the ecological service values of IGS and public preferences can be validated through multi-temporal high-resolution remote sensing imagery and community resident surveys.

## 5. Conclusions

This study coupled a district-scale assessment of UROS with a field survey of IGS in densely built environments to examine where, and through which existing resources, urban rewilding can be activated in a dense metropolitan district. The results reveal the inverse association mechanism between UROI and IGS distribution. UROS in Haidian District form a distinct spatial gradient, from wildness in the mountainous west to high-density built-up zones with low UROI values in the east,

561 with semi-natural successional patches in between. IGS, by contrast, show an inverse distribution:
562 their total area and patch numbers increase as the UROI declines. These areas feature heterogeneous
563 vegetation structures and favourable accessibility conditions. Accordingly, IGS in densely built
564 environments hold substantial potential for urban rewilding.

565 Our study offers the following recommendations for future practice. IGS can be transformed
566 from fragmented, overlooked patches into a functional near-natural habitat network under strategic
567 intervention. To be specific, the shrub layer can be supplemented in 'lots', and public accessibility
568 can be managed in 'gaps'. Accordingly, a cost-effective and socially inclusive pathway can be
569 created for increasing urban biodiversity, ecosystem resilience, and human well-being. On that basis,
570 traditional greening paradigms can transition into a more dynamic and self-sustaining urban ecology.

571

572

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Tan Linying: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Software, Visualization, Validation, Writing – original draft, Writing – review & editing.

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## Data availability

Data will be made available on request.

## Declarations

## Competing Interest

The authors have no relevant financial or non-financial interests to disclose.