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Risk assessment of city site landscapes in the central plains of China

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Abstract

Scientific cognition and assessment of threats to cultural heritage and surrounding landscapes are prerequisites for targeted management and protection of cultural heritage. This study took 530 city sites in the Central Plains of China as the research object. Based on the survey information of city sites in the third national cultural heritage survey in China, a combination of high resolution google images and land use/land cover data products and city sites survey data enables a comprehensive evaluation of landscape elements impacts on city sites. With spatial statistical method, we divided city site landscape types, and constructed a landscape element risk assessment model and an urbanization intensity index to analyze the threats of each landscape element to city site protection. The results indicated that 40.64% of the sites are in farmland landscapes, where agricultural cultivation, irrigation, and other production activities may affect the surface and subsurface remains of the sites. The sites (16.82%) in urban landscapes are affected by activities such as building houses and roads. Only six sites belong to the water landscape area, which may be affected by water erosion. Other sites (2.84%) are mainly affected by plant root growth in forest landscapes. The city sites distributed in urban areas such as Zhengzhou or the urban–rural junction were significantly affected by urban expansion and got the greatest protection pressure. City sites in agricultural landscapes have the second highest conservation risk. Plant erosion and flooding mainly affected the city sites in the northwest-southwest mountainous areas or near the water area of the study area, and the risks were relatively small. It can be seen that landscape types such as urban and farmland, which are closely related to human activities, bring the most pressure to the protection of city sites, and it is necessary to focus on the impact of human activities such as urban construction on city sites and the surrounding environment in the future, while paying attention to the protection and rational use of city sites with high assessment risk in urban planning and management for the protection of the city site proper and landscape scenery.

Keywords City site landscapes, Conservation, Risk assessment, Cultural heritage, Central plains

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Introduction

According to the World Heritage Convention [1], cultural heritage, such as sites, is the product of the joint action of human beings and nature. It has significant historical, cultural, and aesthetic value, is the common wealth of human beings, and is not renewable. As a product of human civilization, after a long period of development and evolution, there is often an inseparable symbiotic relationship between cultural heritage and the surrounding natural and human environments. Cultural heritage protection implies attention to cultural heritage and its surrounding landscapes [2–5].

Urbanization and changes in the natural surface environment will affect the sites differently. For example, urbanization may change the land use/land cover (LULC) pattern in the site area and directly or indirectly affect the cultural heritage and surrounding landscapes. Urban construction and community population activities easily affect cultural heritage. During the urban development process, many infrastructure construction activities may lead to fragmentation or degradation of cultural heritage landscapes and even gradually annihilate and destroy cultural heritage. These threats will lead to irreversible damage to the site and surrounding landscape [6–9]. Natural factors such as the erosion of water bodies (e.g. rivers and oceans) [10, 11] and plant root growth [12] can also threaten the site and the surrounding landscape. For instance, at sites with a high concentration of woody plants, where plant roots flourish, they may gradually encroach on the subterranean remains. Over time, this could even lead to the collapse of the remains [12].

Scientific recognition and assessment of the threats faced by sites and surrounding environment to take appropriate management and preventive measures [13–15] can be considered an essential part of cultural heritage protection and monitoring. Urban expansion and infrastructure construction have been the most critical factors affecting the site's landscape in recent decades, and the research on the impact of LULC changes on cultural heritage and its landscape has attracted much attention [15]. For example, Huirong Yu et al. [16] analyzed the threat of LULC variations, such as urban expansion to the cultural heritage landscape. Pham et al. [17] studied the link between cultural heritage landscape patterns and urban sprawl in Vietnam. Scholars have studied the pressure and risk assessment of heritage protection using a certain factor such as flooding or urbanization [6, 8–10, 12, 17]. However, cultural heritage under different LULC types will face different threats and protection pressures, and there is a lack of objective and quantitative research on evaluating the impact of various surface cover elements on sites from the perspective of cultural heritage landscapes. Thus, considering today's increasingly mature big data technology, it is necessary to apply increasingly rich and accurate surface cover data to heritage landscape protection. A model should be established to verify the impact of landscape elements on heritage protection by combining the previous results on the impact of single factors on heritage and its risk assessment. It will help to perform the heritage landscape protection planning in a targeted manner.

As one of the birthplaces of ancient Chinese civilization, the Central Plains region, with Henan Province as the core, has a long history. It was employed as the Chinese nation's political, economic, and cultural center. The Chinese government performed the third national cultural heritage survey in 2007 [18]. According to the survey data, the number of immovable cultural relics in Henan Province exceeded 65519, accounting for nearly 1/10 of the national total, ranking second in the country. It has 14607 ancient sites, including 16 sub-categories such as city and settlement sites. The 530 city sites in the ancient sites mainly include ancient large-scale ruins surrounded by city walls and moats, which are physical witnesses of ancient city sites and even capitals in the Central Plains [19]. For example, Zhengzhou Shang City, the capital of the early Shang Dynasty in China, located in the central part of the Central Plains, covers an area of about 25 km^2 [20]. The surface of the remnants is an earthen city wall of up to 6 m. Most of the remains are located under the surface of modern cities, and the ruins have faced the pressure of urban construction and cultural heritage protection for a long time [19, 21]. Han-Wei capital city sites is the relic of the capital city left by the Eastern Han, Cao Wei, Western Jin, and Northern Wei Dynasty when their capitals were in Luoyang [22–24]. Most of the relics are located under the surface of farmland and have been affected by agricultural farming activities for a long time [1]. The third national survey of cultural heritage lasted for three years through field investigation, which systematically grasped the types and distribution of immovable cultural relics in different periods in China and recorded the preservation status of cultural heritage. It is well known that large-scale systematic manual field surveys cannot be performed frequently. They will inevitably bring about problems for regional cultural heritage, such as long data update cycle and difficulty in grasping the status quo of cultural relics protection. Remote sensing data can provide a wide range of real-time spatial information, with low cost, high efficiency, and real-time update advantages. It has been widely utilized in cultural heritage risk management, assessment, and other fields [25, 26]. High-resolution remote sensing images, such as the Google and China GF series images, provide a convenient tool for risk monitoring and assessment of cultural heritage and surrounding landscapes. Global LULC data products generated by remote sensing images, such as Sentinel-2 10 m land cover time series of the world from 2017 to 2021 [27] and GlobeLand30 [28], also provide a data basis for monitoring the site landscape variations.

It has been ten years since the last round of cultural heritage surveys. During this period, many immovable cultural relics have changed, especially the surrounding environment of the sites. What is the relationship between the landscapes of the sites and the protection risks? How can we employ remote sensing data products to evaluate the risks faced by the sites quantitatively?

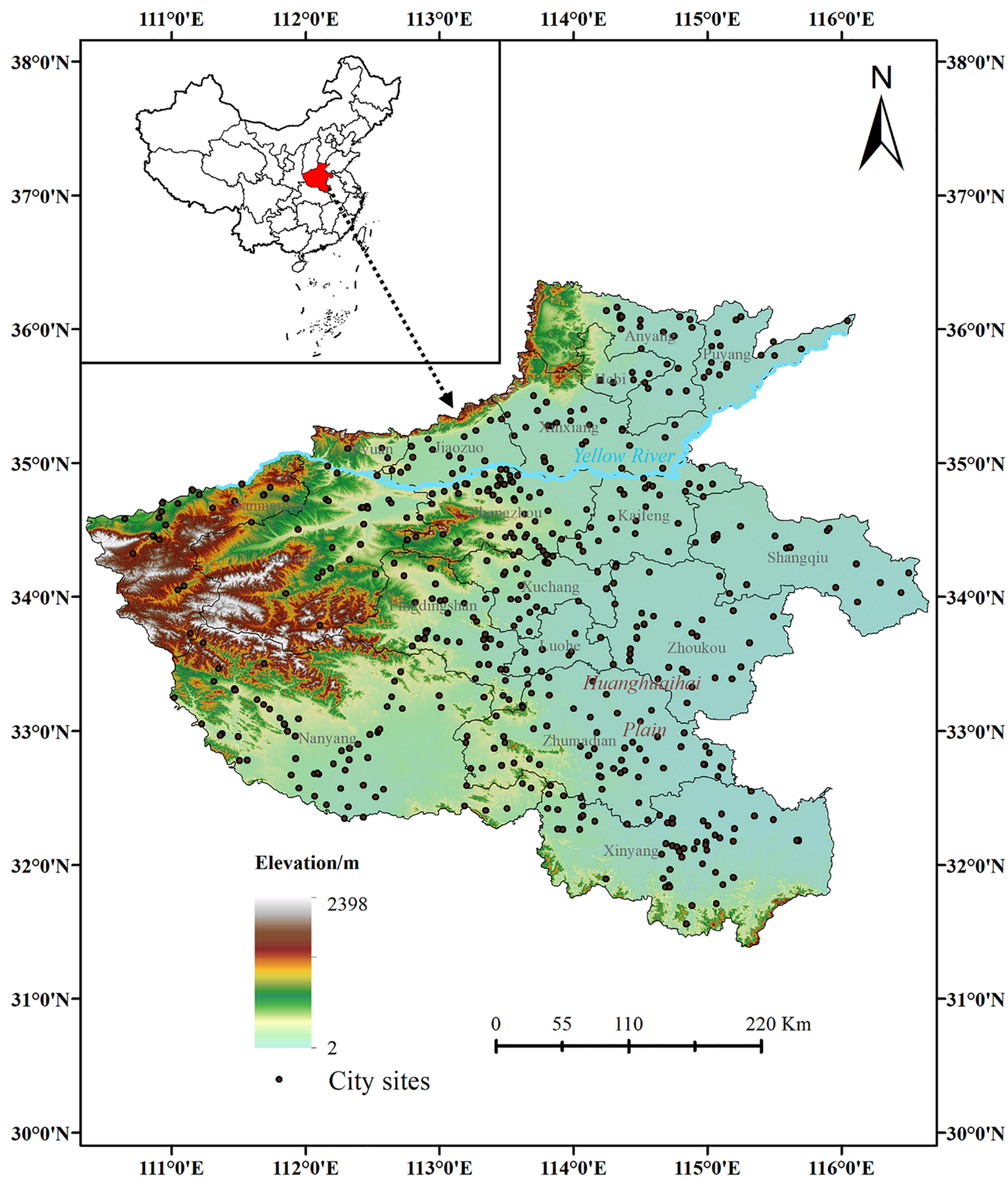

Fig. 1 Location of the research area

Conservation risk will be a fundamental subject for monitoring sites and their environmental safety using remote sensing data in the future. Therefore, this study selects city sites, the most important types among the sites in the Central Plains, and takes their landscapes (their surrounding environment) as the research object. Based on the city site location and attribute information in the third national cultural heritage survey database, the city site landscape types and their existing hazard risk factors are analyzed using high-resolution remote sensing images and LULC data products. Besides, a city site landscape risk assessment model is established to comprehensively evaluate the impact of urbanization, agricultural activities, and other factors on the city site landscapes. This provides a reference for formulating city site protection and management policies for different landscape types.

Materials and methods

Study area

The study area refers to the Central Plains, with Henan Province as the core. It is located in the central and eastern part of China (Fig. 1), between 110°21′-116°39′ east longitude and 31°23′-36°22′ north latitude, with an area of about 165,500 km^2. The terrain is high in the west and low in the east. The Yellow River crosses from the north, of which the plains account for 55.7% [29], while the Huanghuaihai alluvial plain includes the central and eastern parts. According to the data [30], by the end of 2021, the resident population of Henan Province reached 98.83 million, ranking third in the country, and the urbanization level was 64.72%, the regional GDP ranked fifth, and the grain output was 65.4417 million tons, ranking second in the country.

As a central province in population, agriculture, and food production in central China, the Central Plains has been a place with the most frequent human activities for thousands of years. With urbanization and modernization in China since the middle of the last century, regional urbanization speed has increased. In the past two decades, the urbanization rate has increased from 30.65% in 2005 to 64.72% in 2021, and the scope of urban areas has expanded. At the same time, Henan Province is one of the key areas for comprehensive agricultural development [31]. From 1978 to 2018, the annual growth rate of grain production exceeded 1 billion kilograms [32]. The city sites and the surrounding environment will inevitably be affected during urban construction, agricultural production, and other human activities. Besides, the city site landscapes will be constantly transformed, such as building houses, roads, soil borrowing, land leveling, and other human activities around the city sites to varying degrees, influencing the city sites and surrounding environment [21].

Data

This study mainly focuses on the types of city site landscapes and their protection threats. The research data includes city sites survey data and landscape element information. The attribute data of 530 city sites are from the data set of the third cultural heritage survey in Henan Province containing the following key positions:

- Location
- Area
- Dating
- Environment
- Level of preservation

The geographic location of the city site determines the administrative ownership (specifically to the administrative village) where the city site is located and the coordinates of the location of the city site (central point or typical landmark [18]). From the environment attribute, we extracted the surroundings of the city site, such as temperature, rainfall, terrain conditions, and adjacent water areas, as well as nearby settlements and road conditions. Besides, regarding the city site protection at the survey time, the data set also includes the recognized protection level, which indicates whether it is a significant national-level protected site, a provincial-level protected site, or a city and county-level protected site. The protection level reflects the sites' value and importance.

The landscape surface cover data of the city sites were acquired from the ESRI 10 m LULC data in 2017 and 2021, including water, trees, flooded vegetation, crops, built area, bare ground, snow/ice, clouds, and rangeland [33]. At the same time, high-resolution (better than 2 m) Google images of some city sites in 2017 and 2021 were also selected to analyze the surface coverage of fine typical city sites.

Methods

City site landscape scope determining

The city site landscape scope is the region where each city site is monitored. This study employs the city site's coordinates and area data to determine the radius of the city site landscape scope through statistical analysis of the city site area numerical distribution, and the external rectangular delineation method describes the landscape scope of each city site.

Numerical statistical analysis of the area of the city sites

Preliminary statistics on the area attribute values of 530 city sites indicate that the minimum and maximum areas are 0 and 83.2 km^2, respectively (Fig. 2), and the area values of the city sites varied significantly, requiring further analysis of the area attribute characteristics as a basis for the delineation of the radius of the city site landscape scope. For this purpose, the area curve diagram and the kneed inflection point calculation method [34] were selected, the distribution curve of the area attribute value of the city sites was drawn, the inflection point was calculated, and then the city sites were categorized by inflection point.

By drawing the overall distribution curve of the city site area (Fig. 3a) and calculating the inflection point, it is determined that the area of 5 km^2 is the first subsection point. There are 517 sites, accounting for about 97.5% of the total, indicating that most the city sites have an area of less than or equal to 5 km^2. Further statistics of the city site area in the [0,5000000] (m^2) value range are obtained to calculate its inflection point (Fig. 3b), and the value of the second segment point of the city site's area is 1 km^2. Moreover, the city site area distribution map is drawn in the range of [0,1000000] (m^2) (Fig. 3c), and the third area segment point, 22500 (m^2), is obtained. The city sites can be divided into four groups according to the three area segmentation points, as shown in Table 1.

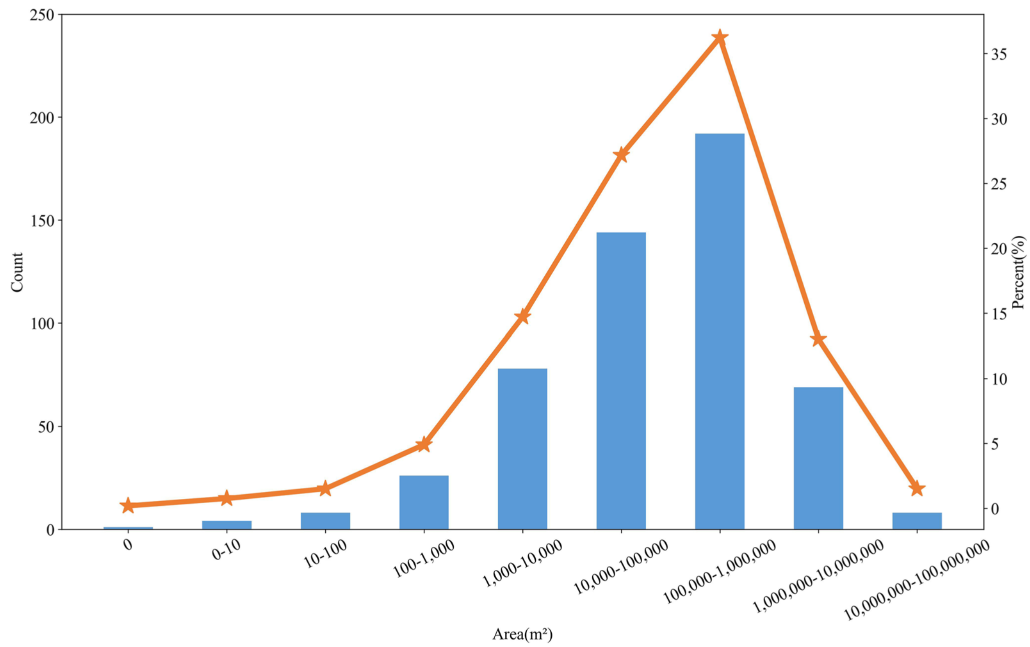

Fig. 2 Distribution of area attribute values of the city sites

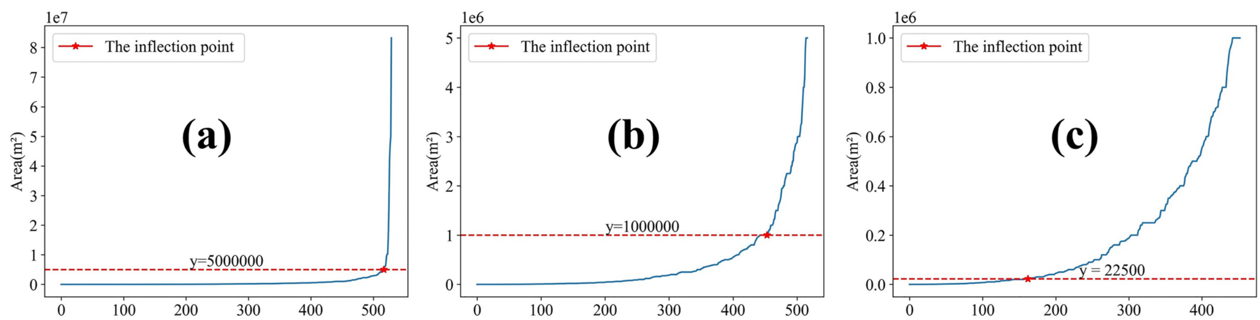

Fig. 3 Distribution curve of the property value of the city site area: **a** as the overall distribution map of the city site area, **b** as the distribution map of the city site area less than or equal to 5 km, **c** as the distribution map of city sites with an area less than or equal to 1 km

Table 1 Groups of city sites

Group	Area attribute value range (m^2)	Number	Percentage (%)
1	[0,22500]	162	30.57
2	[22500,1000000]	291	54.91
3	[1000000,5000000]	64	12.08
4	[5000000,83200000]	13	2.45

The analysis of the attribute values of the area of 530 city sites indicated that the city sites' maximum and minimum area values were significantly different. Combined with the identification and understanding of city sites in settlement archaeology [35–37], the area in the data (Fig. 2, Table 1) was too small (less than 1000 m^2) or too large (greater than 5 km^2), which should be further checked. The rationality of the attribute value of the city site area and the differences in the landscape scope of different groups should be considered while determining the radius of the city site.

Delineation of the landscape scope of the city site

When the city site area is too small or too large, the data sampling inspection and rationality analysis of the city sites with an area of less than 1000 m^2 or more than 5 km^2 are performed by collecting the relevant research data of the sites [38–40].

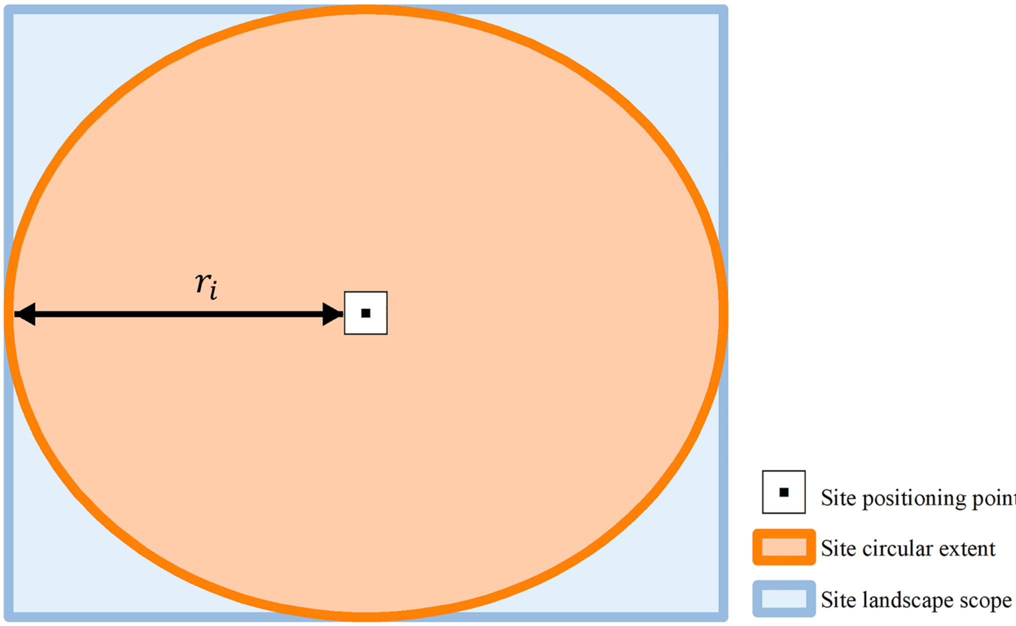

Fig. 4 Determination of city site landscape scope

39 city sites contained too small area attribute values (less than 1 000 m^2) (Fig. 2), where most of their area attribute values were recorded with the area of the remnants on the ground as the city site area record. This means that the area attribute value of the city sites with no remnants on the ground is 0 (such as the city site of Yingyang), and the remaining area of the city site includes a small section of the city wall (such as the ancient city of Beijing, with an area of 1.5 m^2). Therefore, the area attribute value of this part of the city site only represents the area of the remaining relics on the surface, not the actual area of the city site, which is imcompatible with the recording rules of most city site areas in the data table. This situation should be considered while determining the landscape scope of the subsequent city site. Analysis of 13 city sites (Table 1) with too large area attribute values (greater than 5 km^2) indicates that there are three city sites with abnormal area data. Among them, the Chenliujun site with the largest area has an attribute value of 83,200,000 (m^2), which is not compatible with the area of other city sites. It is found that this value (83,200,000) is the area under the jurisdiction of Chen County in the historical period, not the area of the city site [38]. Thus, this value cannot be applied to delineating the city site landscape scope and will be removed. The two other city sites (Qingyang City and Weiguo City) were compared with the relevant research materials, indicating an entirely different area. According to the relevant research results [39, 40], the revised data was utilized to delineate the landscape scope of the city site.

Combined with the analysis of the numerical characteristics of the area and the classification results of city sites (Fig. 2 and Table 1), the actual area is adopted as the basis when determining the city site's landscape scope, and the rationality of the landscape protection scope is considered. For some city sites with an area of fewer than 1,000,000 m^2, a fixed value of 1,000,000 was considered in the calculation, and the city sites larger than this value were considered in the calculation with the actual area data. Based on the coordinates and area data of the city site, the landscape scope was delineated according to the following steps.

(a) Taking the site positioning point as the center, the radius of the site circular extent was delineated as r_i (Fig. 4), and r_i was calculated by the formula (1).

$$r_i = k\sqrt{s_i/\pi} \tag{1}$$

where r_i is the radius of the site circular extent; s_i is the area of the city site; π is the circle's circumference (π= 3.14); k is the radius coefficient. If $k<1$, the area of the site circular extent is smaller than the city site area, and it is challenging for the city site's final delineated landscape scope to include the ruins and the surrounding environment. If the value of k is too large, the landscape scope will be too large, which cannot objectively reflect the city site environment. After several experiments and comparative analysis, $k=1.6$ is considered the final choice.

(b) Based on the site circular extent, the outer rectangle is constructed, and the outer rectangle of the site circular extent is the final landscape scope (Fig. 4).

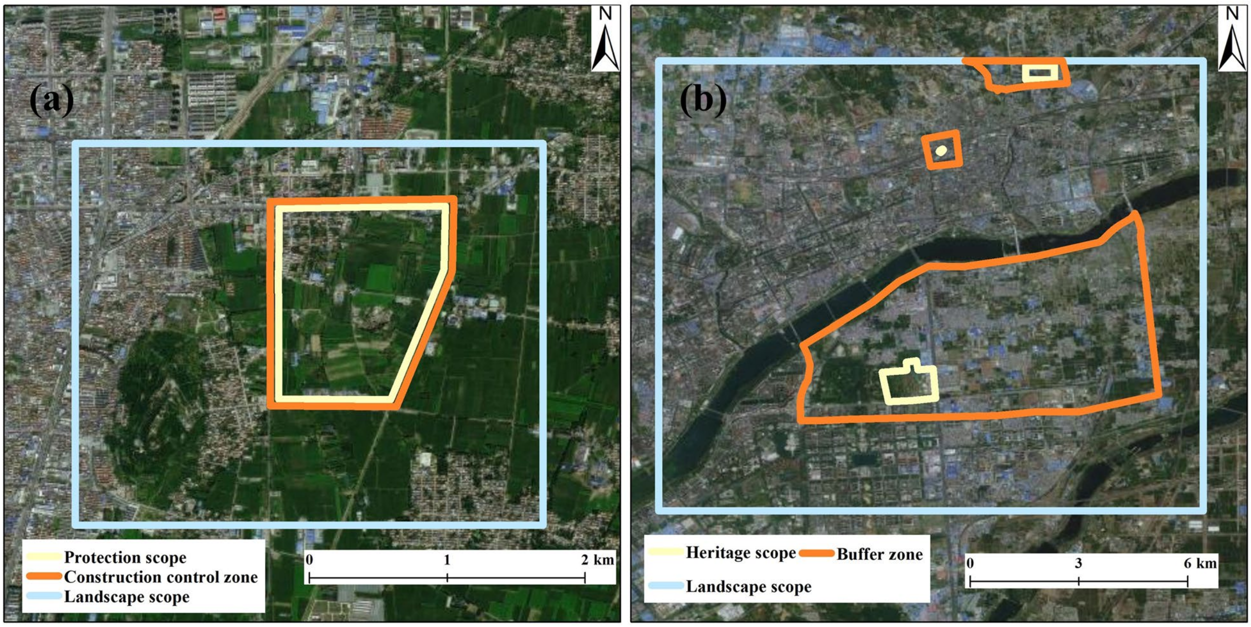

Fig. 5 City site landscape scope test case: **a** is the Sui Tang Luoyang City, **b** is the Liyang city

In order to evaluate the applicability of the landscape scope of the city site and consider the availability of verification data, the Sui Tang Luoyang City and Liyang City were taken as examples. The heritage scope of Sui Tang Luoyang City (world cultural heritage) and its buffer zone [41], the protection scope of Liyang City and the construction control zone[1], and the corresponding city site landscape scope were superimposed for comparative analysis. Figure 5a, b show the Sui Tang Luoyang City and Liyang City with a city site area of 47 km^2 and 1.5 km^2, respectively. The heritage buffer zone (or construction control zone) in Fig. 5 is included in the landscape scope of the city site. The landscape scope covers the information on the actual conservation extent of the site, and the risk analysis of the landscape types conducted in this study is helpful for the conservation of the sites.

City site landscape type division

The dominant LULC type within each city site landscape scope is determined using the 2021 ESRI 10- meter LULC data and based on the proportion of land cover types within the city site landscape scope. Accordingly, the city site landscape is divided and analyzed based on city ruins protection risks in the context of characteristics.

[1] From the field measurement data of Institute of Geographical Sciences, Henan Academy of Sciences.

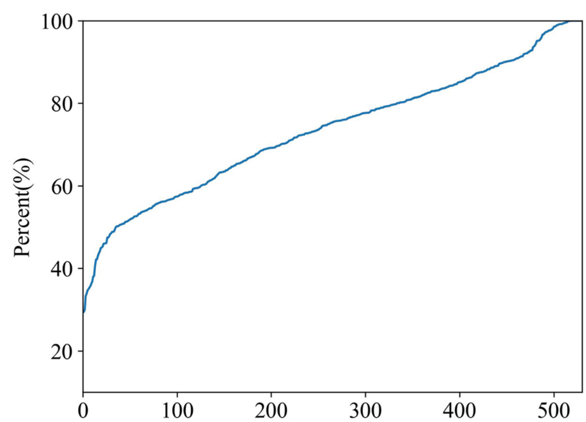

Fig. 6 Distribution map of the maximum proportion of LULC type area

Statistics on the proportion of LULC types

The maximum value of the area proportion is calculated for various LULC types within the landscape scope of each city site, and the distribution of the maximum value of the LULC type area proportion (referred to as"P_{max_i}", the same below) is investigated (Fig. 6). It can be seen that P_{max_i} is between [29.5, 100.0] (%). The value of P_{max_i} within the landscape scope of all city sites is obtained using the grouping analysis tool of ArcGIS, and the value of the grouping boundary point is found to be 71.1%. According to the relevant dominant LULC type classification method [42], the grouping threshold can be determined as

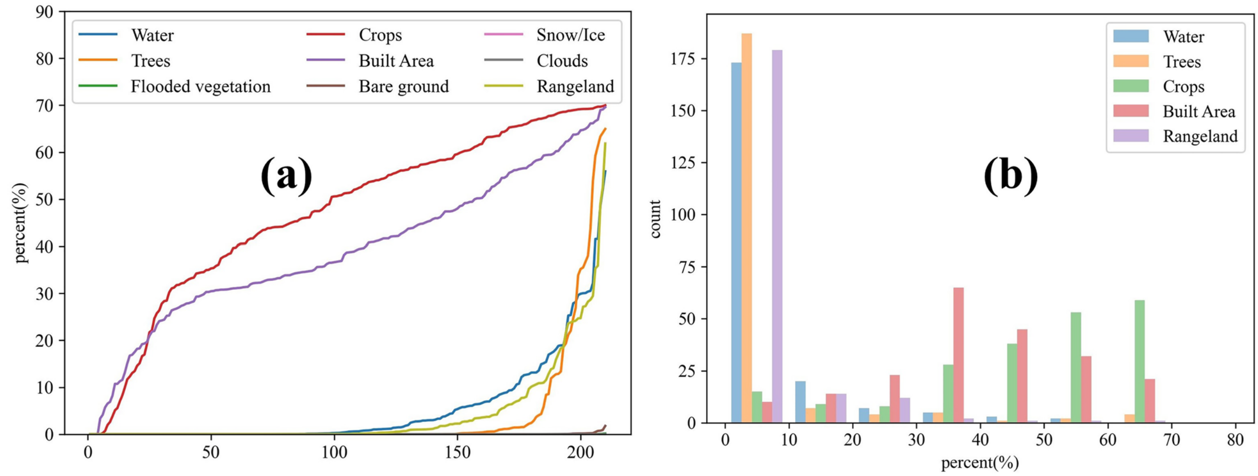

Fig. 7 Statistics of the percentage of LULC types within the landscape scope of 210 city sites with P_{max_i} less than 70%

70%, so the value of P_{max_i} is divided into two groups. Among them, 319 city sites with P_{max_i} greater than or equal to 70% belong to a group. Within the landscape scope, the LULC type with the maximum area proportion has apparent advantages, and its dominant LULC type can be directly determined. The other group P_{max_i} is less than 70% of the 210 city sites with a relatively 'uniform' distribution of the area proportions of various LULC types within the landscape scope. There may be two or more dominant LULC types, and it is necessary to combine various LULC types. The area ratio's actual distribution is comprehensively considered to delineate the dominant LULC type.

The proportion of various land cover types in the landscape was further calculated (Fig. 7) for the 210 city sites with P_{max_i} less than 70%. Since the area proportions of the four land cover types of snow/ice, cloud, submerged vegetation, and bare land are all close to 0 (Fig. 7a), there is no advantage in delineating the dominant land cover type and will not be considered. Analysis of the relationship between the area proportion of five land cover types of water body, forest land, cultivated land, built-up area and grassland (rangeland), and the number of city sites (Fig. 7b) indicates that the proportion of water body area is less than or equal to 10%. There are 173 city sites, 187 city sites with forest land area accounting for less than or equal to 10%, 179 city sites with grassland area accounting for less than or equal to 10%, 178 city sites with cultivated land area accounting for more than 30%, and 163 city sites with built-up area accounting for more than 30%.

Determination of dominant LULC types

Analysis of the proportion of LULC types within the landscape scope of 529 city sites shows that P_{max_i} is greater than or equal to 70% with the landscape scope of 319 city sites, and the LULC type with the maximum area proportion has advantages and can be divided into the dominant LULC type. While as for the remaining 210 city sites with $P_{\ max\_i}$ less than 70%, most of the two dominant LULC types exist at the same time, the sum of their area proportion is greater than or equal to 70%. Accordingly, the dominant LULC type is determined as follows: assume that within the landscape scope of the i-th city site, the set of LULC types and the set $LULC_{(i)}$ of corresponding area proportions of various LULC types correspond $P_{(i)}$ to formulas (2) and (3), respectively, then the dominant LULC type corresponding to the $DLULC_{(i)}$ for the i-th city site can be calculated form formula (4).

$$\begin{aligned} LULC_{(i)} &= \{l_1, l_2, \ldots, l_j\}(j \le 9) \\ &= \{\text{"Water", "Trees", "Flooded vegetation",} \\ &\quad \text{"Crops", "BuiltArea", "Bareground",} \\ &\quad \text{"Snow/Ice", "Clouds", "Rangeland"}\} \end{aligned} \tag{2}$$

$$P_{(i)} = \{p_1, p_2, \ldots, p_j\} \tag{3}$$

$$DLULC_{(i)} = \begin{cases} l_{max\_i}, p_{max\_i} \ge \partial \\ l_{max\_i} \cup l_{max2\_i}, p_{max\_i} < \partial and p_{max\_i} + p_{max2\_i} \ge \partial \\ mixed, p_{max\_i} < \partial and p_{max\_i} + p_{max2\_i} < \partial \end{cases} \tag{4}$$

Among them, p_{max_i} and p_{max2_i} are the maximum and the second maximum values of $P_{(i)}$, respectively, and then corresponding LULC types are l_{max_i}, $l_{max2\_i}($

Table 2 Classification of city site landscape types

DLULC	Landscape categories	DLS
l_1("Water")	Water	Water
$l_2, l_9, l_2 \cup l_9$("Trees", "Rangeland")	Forest grass	Forest grass
l_4("Crops")	Farmland	Farmland
l_5("BuiltArea")	Urban	Urban
$l_1 \cup l_2, l_1 \cup l_9$("Water","Rangeland","Trees")	Hybrid	Water-forest grass
$l_1 \cup l_4$("Water","Crops")		Water-farmland
$l_1 \cup l_5$("Water","BuiltArea")		Water-urban
$l_2 \cup l_4, l_9 \cup l_4$("Trees", "Crops")		Forest grass-farmland
$l_2 \cup l_5, l_9 \cup l_5$("Trees", "BuiltArea")		Forest grass-urban
$l_4 \cup l_5$("Crops", "BuiltArea")		Farmland-urban
Mixed		Various combinations

$l_{max\_i} \in LULC_{(i)}, l_{max2\_i} \in LULC_{(i)}$), and ∂ is the threshold value that can be determined according to the distribution of the area proportions of various LULC types within the landscape scope of 529 city sites. Here, $\partial = 70$ is considered.

Classification of city site landscape types

Based on the grouping results of LULC types, the $DLULC_{(i)}$ and $DLS_{(i)}$ of city site landscape types can be divided, as shown in Table 2.

Extraction of risk factors and the assessment model construction for landscape protection of city sites

Due to the different landscape types and ontology characteristics, the sites' protection risks will differ. The risk factors of the city site landscape were extracted by combining the city site landscape type and the city site environment information in the third cultural heritage survey data set, and a risk assessment model was established to evaluate the protection risks faced by the city site landscape.

Risk factors for city site landscape protection

According to the field survey information about the city site environment in the site attribute table, the description sentences related to the city site landscape protection risk are extracted, and the city site landscape protection risk is organized into four factors: urban construction, agricultural production, flooding, and plant erosion (Table 3):

Urban construction Towns are areas with human activities. In order to build houses, roads, and other infrastructure, people's activities, such as borrowing soil, may damage the city walls. New buildings may encroach on the site area and affect the city site landscape integrity. The garbage generated by people's lives may pollute the city. In heritage environments, these risks tend to intensify with town development.

Agricultural production Cultivated land is the area for agricultural production activities. Cultivation, irrigation, and canal repair may cause damage to the surface or underground shallow distribution remains.

Flooding Most city sites in the Central Plains are soil sites [37] in or near water environments. They are susceptible to water erosion and erosion, and the seasonal and periodic flooding and flooding of rivers (such as the Yellow River) may even submerge the entire site landscape.

Plant erosion The woodland and grassland environment are well-developed, and the root system of plants may affect the underground remains. Over time, the remains will gradually erode, which may collapse the remains.

The four influencing factors of urban construction, agricultural production, flooding, and plant erosion mainly correspond to the five LULC types, including built area, crop, water, trees, and rangeland. Based on the latest (2021) high-resolution LULC products, refer to the site risk assessment methods [43–46], we used a weighted sum model to assess the impact of five LULC types on the city site landscapes in the Central Plains. Besides, considering that the impact of urban expansion on the site landscapes is evident, an urbanization intensity index [17] was constructed in the study to analyze the impact of urban expansion on the site landscapes during 2017–2021.

Landscape element risk assessment model (LERAM$_i$)

With the help of the field survey information during the third cultural heritage survey, we sampled and

Table 3 Extraction of risk factors for city site landscape

Name	Risk description	Threat factors	Risk type	LULC	$DLS_{(i)}$
Changmiao	The site was destroyed by nearby residents who built houses, opened kilns, and borrowed soil	Building houses, opening a kiln, borrowing soil	Urban construction	Built area	Urban
Laozhuangzhaihao	It was occupied by building houses	Building houses	Urban construction	Built area	Urban
Pinggao	Long-term farming	farming	agricultural production	crops	farmland
heyang	A section was dug out due to the school building	Building houses	Urban construction	Built area	Urban
Zhuchengcun	Due to long-term agricultural production activities, the site has been damaged to some extent	Agricultural production activities	Agricultural production	Crops	Farmland
Neixiang	Since liberation, due to man-made factors such as the construction of new urban areas, the production and living activities of urban residents, unreasonable development and utilization, population increase, road widening, and building renewal, the ruins of the ancient city in Neixiang gradually disappeared	Population increase, road widening, housing renewal	Urban construction	Built area	Urban
Baiting	Reservoir water erosion, soil erosion	Reservoir flushing	Flooding	Water	Water
Mangxian	The yellow river flooded and silted up	Siltation of the yellow River	Flooding	Water	Water
Ancheng	Years of cultivation have caused certain damage to the surface of the site	Long-term cultivation	Agricultural production	Crops	Farmland
Shaoyue	Because the southern part of the old city of Zhaoyue is adjacent to the Bishui River, the terrain is relatively low-lying, and the southern part of the city site was scoured by the river, causing certain damage	River wash	Flooding	Water	Water
Chongmen	Tree roots have a certain eroding effect on the city site	Erosion of tree roots	Plant erosion	Trees, rangeland	Forest grass

Table 4 Weights of the LULC types

LULC types	Weights
Built area	5
Crops	2
Water	2
Trees and rangeland	1

extracted environmental information from some of the city sites (Table 3). Based on the results of the sampling and extraction, the impact coefficients of LULC types (e.g. built area) were synthesized by referring to the opinions of different experts and scholars with Delphi method, and the risk assessment model of landscape elements was finally weighted and constructed as Eq. 5.

$$\mathrm{LERAM_i} = \frac{\mathrm{w_{bi}A_{bi} + w_{ci}A_{ci} + w_{wi}A_{wi} + w_{ti}A_{ti}}}{\mathrm{A_i}} \tag{5}$$

$\mathrm{LERAM_i}$ is the assessment risk value of the landscape elements of the i-th city site; $\mathrm{A_i}$ is the landscape area of the i-th city site; $\mathrm{A_{bi}}$, $\mathrm{A_{ci}}$, $\mathrm{A_{wi}}$, and $\mathrm{A_{ti}}$ are the areas of the built area, crops, water, trees, and rangeland within the i-th city site landscape range in 2021; $\mathrm{w_{bi}}$, $\mathrm{w_{ci}}$, $\mathrm{w_{wi}}$, and $\mathrm{w_{ti}}$ correspond to the influencing weights of landscape elements of built area, crops, water, trees, and rangeland, respectively, as shown in Table 4.

Urbanization intensity index ($\mathrm{UII_i}$)

$$\mathrm{UII_i} = \frac{\Delta \mathrm{A_{bi}}}{\mathrm{A_i}\Delta \mathrm{t}} \tag{6}$$

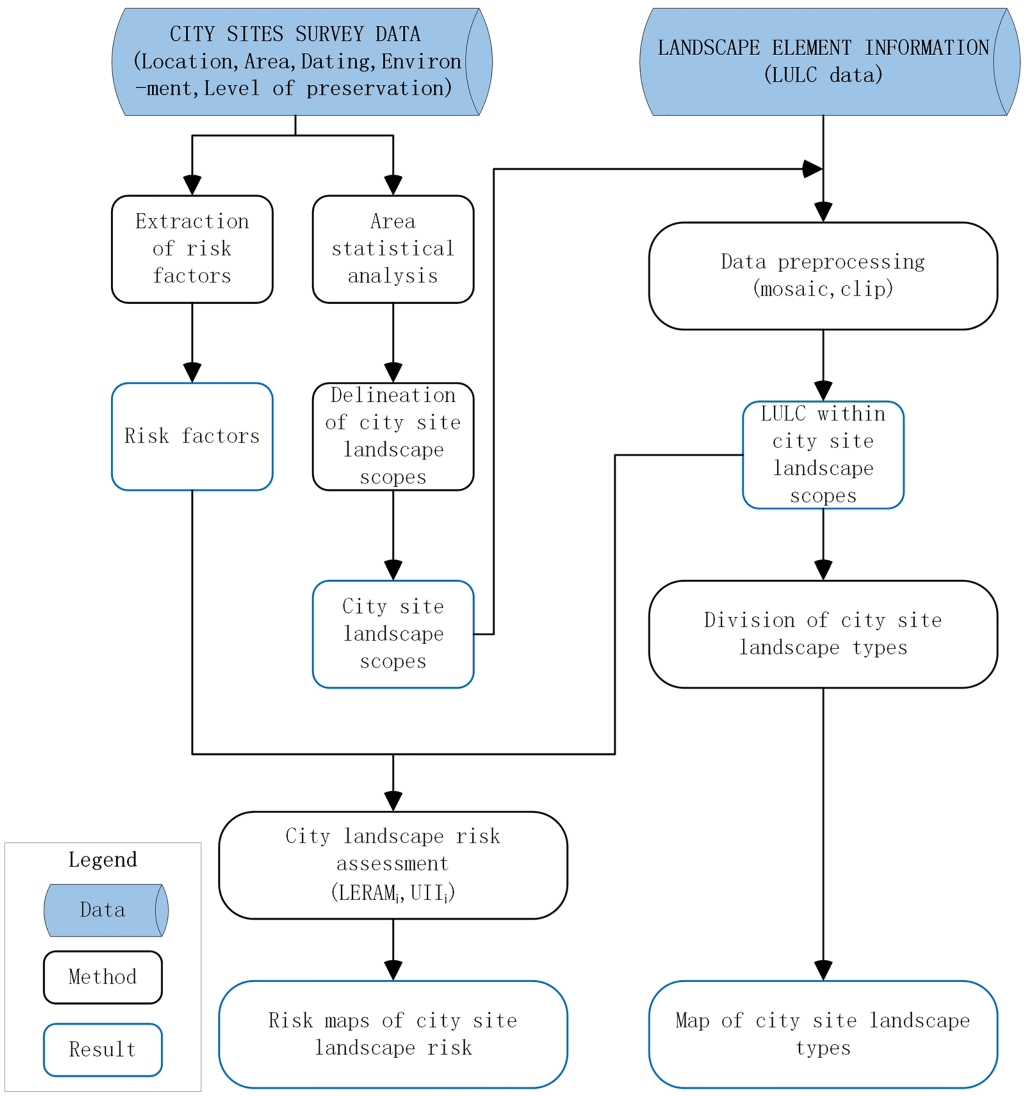

Fig. 8 Flowchart of the methodological framework used in this study

UII_i is the urbanization intensity index within the landscape scope of the i-th city site, and A_i is the area of the city site's landscape scope; ΔA_{bi} is the value of the change in the built-up area within the city site's landscape scope between 2017 and 2021; Δt is the period, which equals 4 between 2017 and 2021.

Main steps of the methodological framework

The main steps of methodological framework in the study are summarized with the flowchart in Fig. 8. Based on the city sites survey data, the risk factors and distribution characteristics of the statistical area attribute value are extracted, respectively. Combined with the statistical characteristics, the city site landscape scope determination method is used to obtain the city site landscape scopes. With the help of the city site landscape scopes, we mosaicked and clipped the LULC data, and then we obtained the landscape element information within the landscape scope of each city site. The map of city site landscape types was obtained by using city site landscape type division method in combination with the landscape element information, to qualitatively analyze the conservation threats to the city site landscape in the Central Plains. The risk factors of the city site and the information of landscape element within the landscape of each city site were used as the input data of the risk assessment model, and finally the risk distribution map of the city site was obtained to quantitatively assess the impact

Table 5 Classification results of city site landscape types

landscape categories	landscape type	Number of city sites	Percentage (%)
Farmland	Farmland	214	40.45
Urban	Urban	89	16.82
Forest grass	Forest grass	15	2.84
Water	Water	6	1.13
Hybrid	Farmland-urban	164	31
	Water-urban	9	1.7
	Forest grass-farmland	7	1.32
	Water-farmland	5	0.95
	Forest grass-urban	4	0.76
	Water-forest grass	1	0.19
	Various combinations	15	2.84

of each landscape element on the conservation of the city sites.

Results and discussion

Landscape elements of city site and their corresponding risks

According to the city site landscape division results (Table 5, Fig. 9), 215 of the 529 city sites belong to farmland landscape, the maximum number accounting for 40.64% of the total. Farmers in this landscape have long-term farming, reclamation, and other agricultural production activities, affecting surface or shallow surface relics. Eighty-nine city sites belong to the urban landscape and are mostly concentrated in Zhengzhou and surrounding areas. Zhengzhou and other areas have high population density and urbanization rates [31]. City sites in this landscape are easily affected by house construction and road construction. The landscape scope of 15 city sites is located in densely distributed areas of forest and grass, mainly in the northwest and southwest mountainous areas, and plant root encroachment and erosion easily threaten the sites. The 6 city sites belong to the water landscape area, and the erosion of water and the deposition of rivers may cause damage to the sites to a certain extent.

In order to further analyze the comprehensive impact of various landscape elements on city site protection, the risk values of landscape elements for all city sites in 2021 were calculated based on the risk assessment model of landscape elements. Besides, they were divided into five levels I, II, III, IV, and V (Table 6) using the natural breaks (Jenks) division method. The risk assessment results of the city site landscape elements (Table 6 and Fig. 10) indicate that the landscape types corresponding to the city site landscape element risk value from high to low are urban, farmland, water, and forest and grass.

Among them, 89 city sites with the highest risk level (V) of landscape elements are located in the urban landscape, in or near built-up areas, and are likely to face urban construction risks. For example, Zhengzhou Shang City is located in the central area of the old city of Zhengzhou, with a high population density. The newly built artificial facilities, such as houses and buildings within the site landscape, are densely distributed (Fig. 11a), affecting the city site landscape's integrity and aesthetics. Relevant studie [47] have also indicated that people will produce much domestic waste and wastewater daily, which will lead to a dirty, chaotic, and poor landscape environment, threating the site.

Flooding and plant erosion mainly affect the city sites in the northwest-southwest mountainous areas or near water areas, and the risk level of landscape elements is the lowest (I). For example, the Taihezhai site of Ma'anqiao is a walled city on the top of a mountain, surrounded by mountains (Fig. 11b), and the densely distributed tree roots may affect the underground remains. The Xinghua City is located at the front of the first-class terrace on the south bank of the Danjiang, with small ditches and depressions to the east and west. The Danjiang passes through the northern part of the site's landscape scope (Fig. 11c), where water scouring and erosion threaten the site's conservation. For city sites in forest and water landscapes, it is necessary to monitor and predict the site and the environment during protection to avoid long-term erosion of plant roots and water flow from causing severe damage to the site and appropriately implementing conservation measures such as cutting on the premise of making a balance between preserving the plant system stability and the site stability [12]. We should also plant native plants on the river banks to avoid soil erosion and the spread of water erosion [10].

Most of the II-risk city sites are in farmland landscapes, and the sites are easily affected by agricultural production activities. For example, Kangwang City in the Han Dynasty was almost entirely a farming environment (Fig. 11d). The survey data indicated that the city wall was built with rammed earth, and the surrounding farmers excavated ditches, plowed the land, borrowed, and dug during the production activities. Such actions may damage surface remains, and crop roots may affect some less buried remains. Han-Wei capital city is located at the starting point of the Chang'an-Tianshan Corridor World Cultural Heritage. City site protection has received significant attention [48]. Relics such as Yongning Temple and palace remain on the ground, surrounded by cultivated land and roads (Fig. 11e). The site area protection and management planning system

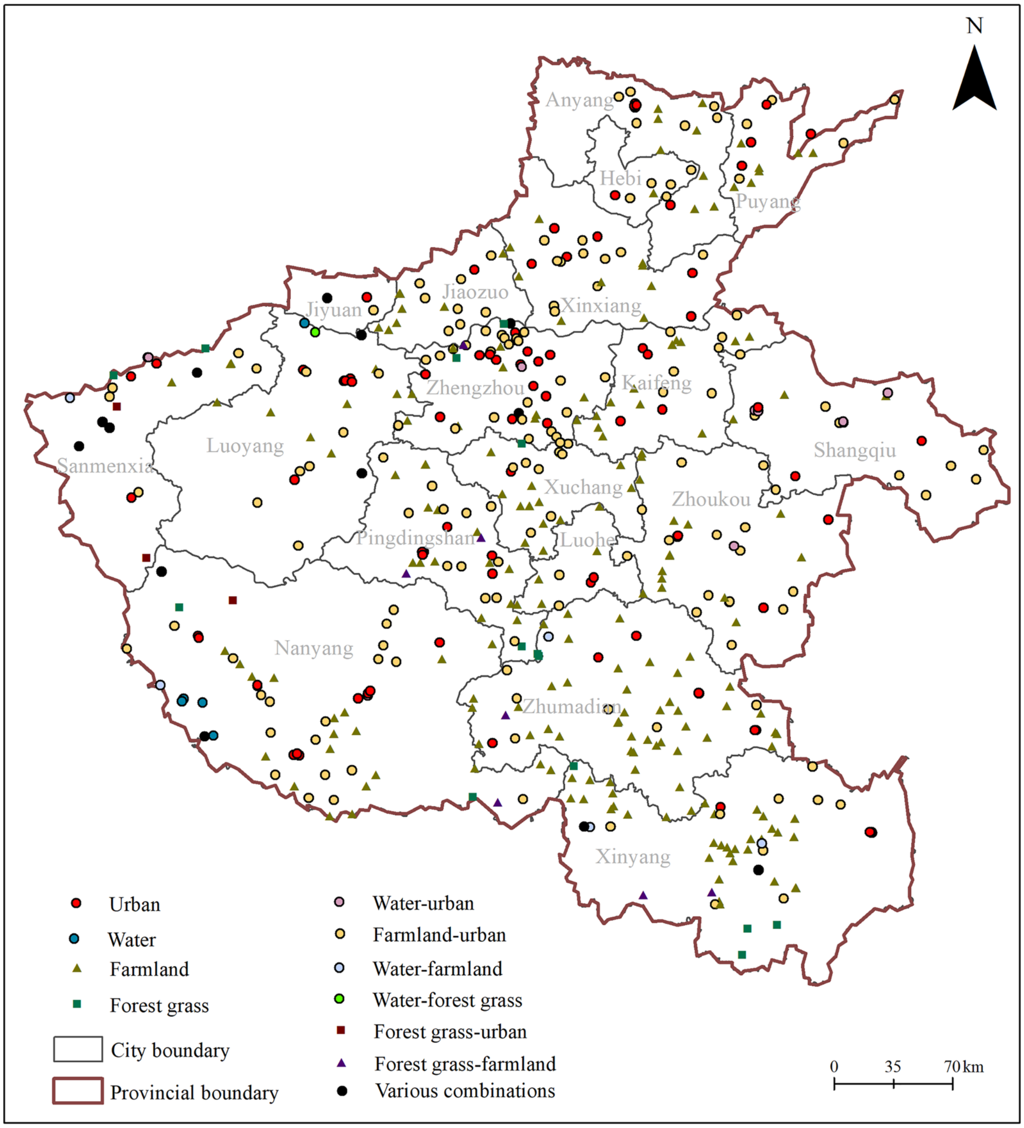

Fig. 9 The result of landscape division result of the city sites, the map of city site landscape types

has been improved under the supervision of protection agencies such as the National Archaeological Site Park of the Han-Wei capital city and the World Cultural Heritage Management Office [48], and the surrounding farmers' production and urban construction activities are subject to heritage protection regulations [49]. Appropriate transportation facilities have driven the development of local sustainable tourism, making residents' lives, regional economic development, and heritage protection complementary, which can provide a reference for sustainable conservation planning for other city sites.

Most of the city sites with III and IV risk levels are in diverse landscapes, influenced by two or more landscape elements such as urban, farmland, water, and forest and grass. For example, there are many artificial facilities such as buildings and roads in the landscape scope of Kangbei

Table 6 Landscape element risk assessment results

$LERAM_i$	Risk levels	Number	Percentage (%)	$DLS_{(i)}$
1.0–1.8	I	19	3	Forest grass, water, etc
1.8–2.6	II	162	31	Farmland, etc
2.6–3.2	III	164	31	Hybrid
3.2–4.1	IV	95	18	Hybrid
4.1–5.0	V	89	17	Urban

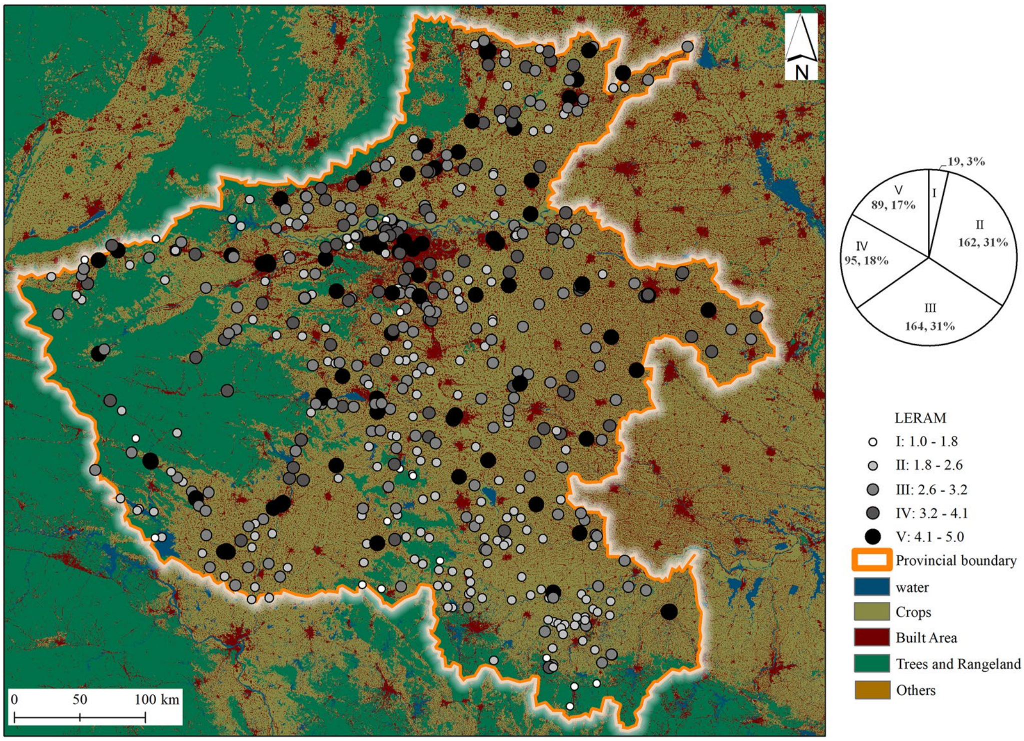

Fig. 10 Landscape element risk assessment results

City. The Yiluo River on the east side of the site positioning point runs through the entire site area (Fig. 11f). Urban construction and water erosion may affect the site. Scholars [19] have indicated that factors such as urban expansion pose a significant threat to site protection.

Urbanization pressure

Human activities such as urban construction significantly influence the site landscape. This study employed the urbanization intensity index to analyze the expansion of built-up areas within the city site landscape from 2017 to 2021 and its impact on the city ruins. The calculation results of the urbanization intensity within the landscape scope of each site (Fig. 12) reflect that the city sites distributed in urban areas such as Zhengzhou City or the urban–rural junction are significantly affected by urbanization, and the pressure on cultural heritage protection is the greatest, and they should focus on future conservation and management even for a small number (1% of the total). For example, the urban construction land has increased significantly within the landscape scope of Gupingqiu Site and Guchengcun City, which have a high urbanization intensity index. The risk level of landscape elements is the highest (V-level risk, refer to Table 6 and Fig. 10). The high-resolution historical images of Google Earth (2017–2021) indicated that the elements within the landscape scope of these city sites had changed significantly, and the city site environment is generally affected by urban expansion activities such as road construction and house building, significantly changing the city site landscape appearance.

During the four years from 2017 to 2021 (Fig. 13a, b), the built-up area has expanded by 39.15% within the landscape scope of the Gupingqiu Site of the Eastern Zhou Dynasty. In 2017, the city site was still at the southern edge of the built-up area, with only the man-made construction area in the north. By 2021, many new buildings were added to the city site's east, west, and south sides. Artificial buildings have surrounded the city site, and the landscape appearance of the city site has been completely Changed. According to the third cultural heritage survey records, Gupingqiu Site is mainly underground, and there are no remains on the surface, which may destroy potential archaeological features during the construction of the town and engineering facilities [6].

Another typical example is Guchengcun site in the Spring and Autumn Period, which has existed for more than 2000 years. It is located at Gucheng Village, Longhu Town, Zhengzhou City. In the past four years, a newly constructed road has passed through the northwest of Guchengcun City. (Fig. 13c, d), which runs through the entire landscape scope of the site. At the same time,

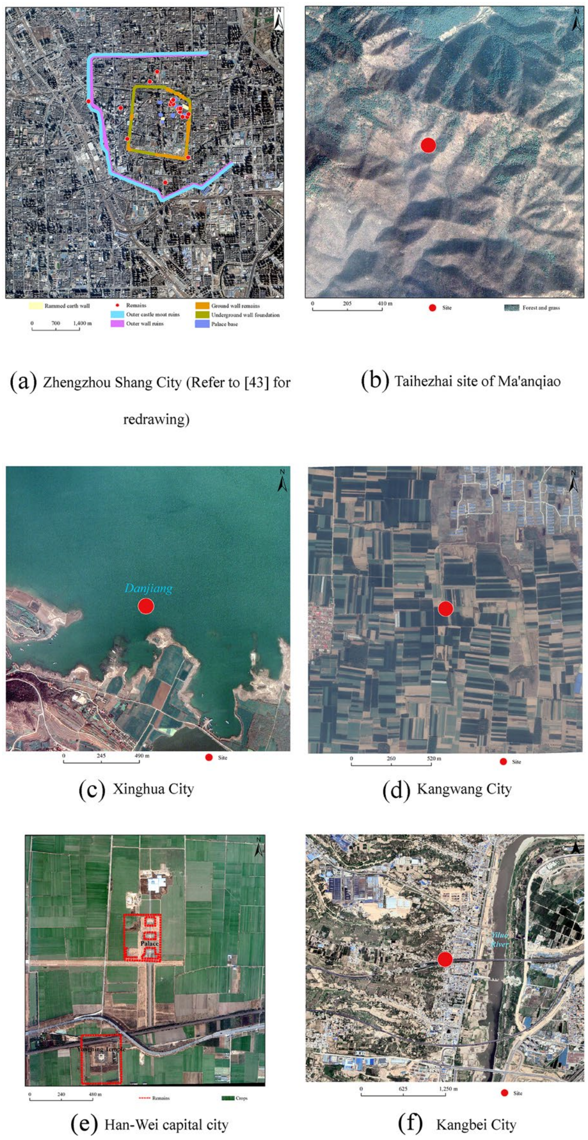

Fig. 11 City site landscapes and risks [43].

new artificial buildings were built in the northeast of the site, seriously affecting the landscape appearance of the site. The survey data indicate that the city wall cliffs and rammed earth layers are still preserved at the site. The city site has preserved rubble layers, ash pits, building materials, and pottery fragments. People's activities, such as borrowing soil to build houses and roads, will seriously damage the relics. The continuous vehicle vibration caused by the newly-built roads will also affect the structural stability of the adjacent city walls and other relics. The pollutants released by vehicles may also indirectly accelerate the degradation of monuments [6], threating site protection.

Conclusions

The third survey of cultural heritage in Henan Province (2007–2011) recorded the protection status of city sites in the Central Plains. With the influence of urban construction and other human activities, the LULC within the landscape scope of city sites in the Central Plains has significantly changed in the past ten years, and the city site landscape is facing various protection pressures. Based on the third cultural heritage survey data set, combined with high-resolution remote sensing images and LULC data, this study selects landscape elements, such as urban, farmland, water, and forest and grass, to analyze the threats to the city site protection, and comprehensively assesses the risks of conserving city sites in the Central Plains region. The main conclusions are as follows:

(1) Urban construction, agricultural production, flooding, and plant erosion mainly threaten city sites in the Central Plains. Among them, 40.64% of the city sites are in farmland landscapes, where agricultural cultivation, irrigation, and other production activities may influence the surface and underground remains of the city sites. The city sites, with 16.82%, are in the urban landscapes. During urban construction, large-scale construction of houses and roads changes the city sites' landscape appearance and may damage the surface or subsurface remains of the city sites. Besides, 2.84% of the city sites are in forest and grass landscapes, where the remains are susceptible to erosion by plant roots due to the secondary radial growth of woody plants. The city sites with 1.13% are in water landscapes, and the sites are vulnerable to flooding, immersion, and river bank erosion due to the accumulation of silt, water erosion, and soil erosion.

(2) City sites in or adjacent to built-up areas face the highest risk, city sites in landscape types such as forest and grass are less likely to be affected, and landscape types closely related to human activities face the maximum protection pressure. For city sites in the urban landscape with high protection risks, cultural heritage landscape protection should be incorporated into the overall design during urban construction, such as building site parks, to promote site protection, and archaeological promotion to foster community awareness of cultural heritage conservation [8, 21].

(3) Urban expansion significantly affects the city sites distributed in urban areas such as Zhengzhou city

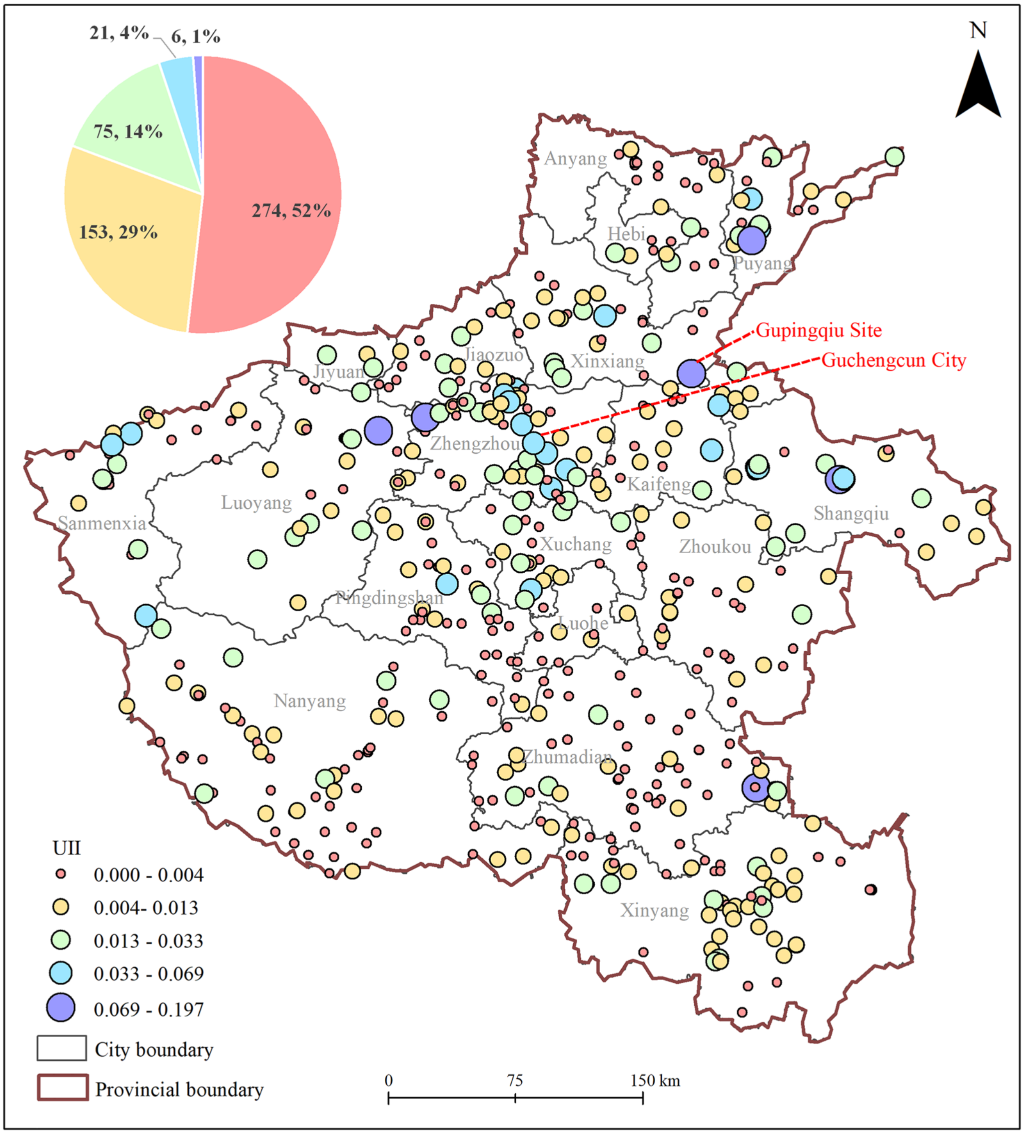

Fig. 12 Urbanization Intensity Index

or the urban–rural junction, and the pressure on landscape protection is the greatest. In the future, it is necessary to pay more attention to urban planning and site protection.

Compared with previous studies, this study comprehensively analyzed the possible risks of city site protection from landscape elements, such as urban, farmland, water, and forest and grass. Accordingly, the impacts of town construction (expansion), agricultural production, flooding, and plant encroachment on cultural heritage landscapes were comprehensively assessed. The relevant methods can provide a reference for regional cultural heritage landscape risk assessment. The analysis results of city site landscape characteristics are the basis for comprehensively understanding city sites environment and risk types and assessing and managing cultural heritage in a targeted manner. The city site landscape risk assessment results are essential for decision-makers to formulate cultural heritage protection plans. It has been ten years since the third survey of cultural heritage. The central future study aspect is to verify the change in the sites and their landscape risk factors during these ten years. The construction of a real-time monitoring system of cultural heritage landscape risk should also be considered by combining the latest near real-time remote sensing images and LULC data [50].

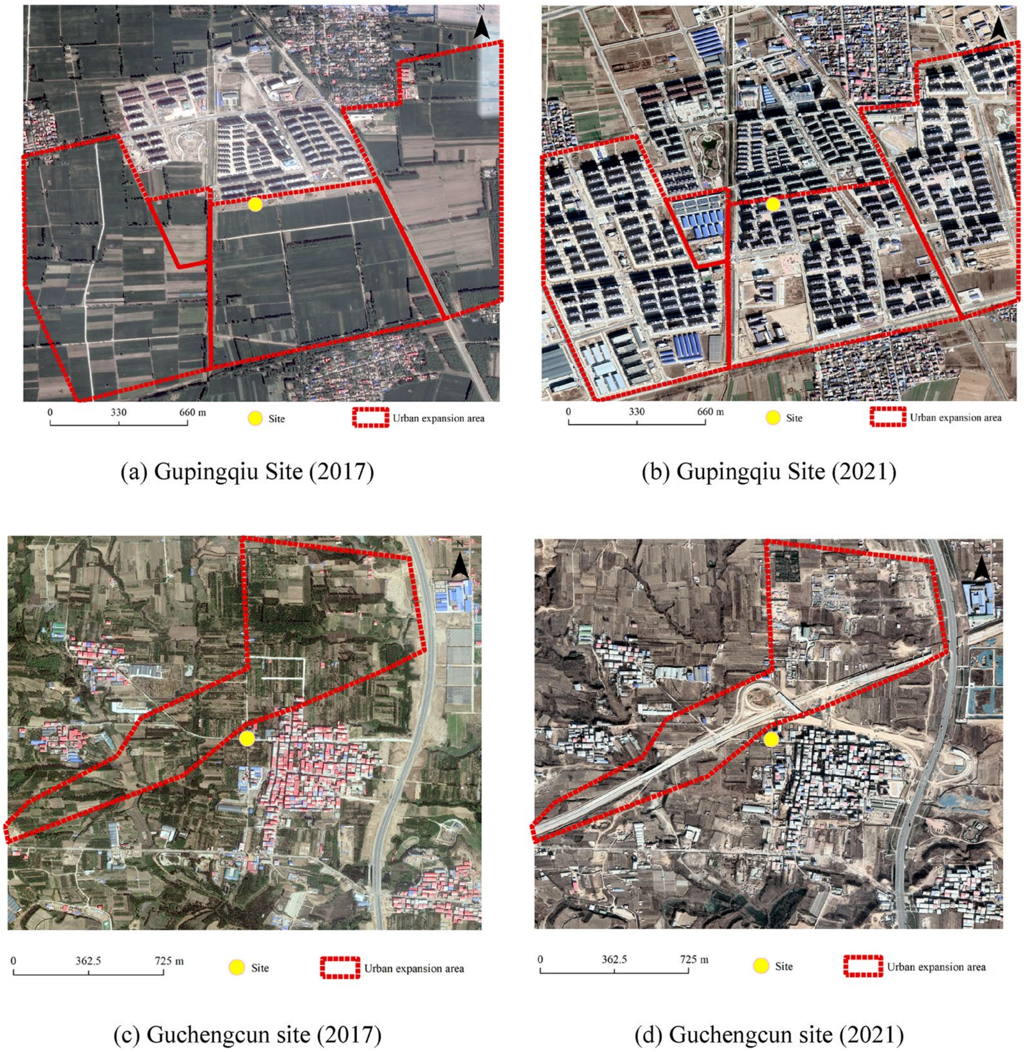

Fig. 13 Impact of urban expansion.

Abbreviation
LULC The land use/land cover

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Author contributions
Conceptualisation: RY and WL; data curation: WL, RY, and LY; formal analysis: WL and RY; methodology: WL and RY; visualisation: WL and RY; writing—original draft preparation: WL and RY; writing—review and editing: WL, RY, YX, and HL; funding acquisition: FC and LY. All authors have read and approved the final manuscript.

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Availability of data and materials
The data sets used or analyst during the current study are available from Wei Li upon reasonable request, and her email address is liwei20@mails.ucas.ac.cn.

Declarations

Ethics approval and consent to participate
Not applicable.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

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References

1. World Heritage Centre. Basic texts of the 1972 world heritage convention. UNESCO. 2021. https://whc.unesco.org/en/basictexts/. Accessed 13 Jan 2023.
2. Ahmad Y. The scope and definitions of heritage: from tangible to intangible. Int J Herit Stud. 2006;12(3):292–300.
3. Vecco M. A definition of cultural heritage: from the tangible to the intangible. J Cult Herit. 2010;11(3):321–4.
4. Grazuleviciute-Vileniske I, Matijosaitiene I. Cultural heritage of roads and road landscapes: classification and insights on valuation. Landsc Res. 2010;35(4):391–413.
5. Elfadaly A, Attia W, Qelichi MM, Murgante B, Lasaponara R. Management of cultural heritage sites using remote sensing indices and spatial analysis techniques. Surv Geophys. 2018;39(6):1347–77.
6. Agapiou A, Alexakis DD, Lysandrou V, Sarris A, Cuca B, Themistocleous K, et al. Impact of urban sprawl to cultural heritage monuments: the case study of Paphos area in cyprus. J Cult Herit. 2015;16(5):671–80.
7. Bonazza A, Maxwell I, Drdácký M, Vintzileou E, Hanus C. Safeguarding Cultural Heritage from Natural and Man-Made Disasters: a comparative analysis of risk management in the EU. Publications Office of the European Union; 2018.
8. Kristy G. The impact of urban sprawl on cultural heritage in Herat, Afghanistan: a GIS analysis. Digital Appl Archaeol Cultural Heritage. 2018;11: e00086.
9. Xiao D, Lu L, Wang X, Nitivattananon V, Guo H, Hui W. An urbanization monitoring dataset for world cultural heritage in the belt and road region. Big Earth Data. 2022;6(1):127–40.
10. Bharasa P, Gayen A. Safeguarding the threatened hydrogeo-cultural heritage of Majuli Island in Assam, India: a case study. IOP Conf Series Earth and Environ Sci. 2021. https://doi.org/10.1088/1755-1315/597/1/012025.
11. Vousdoukas MI, Clarke J, Ranasinghe R, Reimann L, Khalaf N, Duong TM, et al. African heritage sites threatened as sea-level rise accelerates. Nat Clim Chang. 2022;12(3):256–62. https://doi.org/10.1038/s41558-022-01280-1.
12. Caneva G, Benelli F, Bartoli F, Cicinelli E. Safeguarding natural and cultural heritage on Etruscan tombs (La Banditaccia, Cerveteri, Italy). Rendiconti Lincei Scienze Fisiche e Naturali. 2018;29(4):891–907.
13. Romão X, Paupério E, Pereira N. A framework for the simplified risk analysis of cultural heritage assets. J Cult Herit. 2016;20:696–708.
14. Pavlova I, Makarigakis A, Depret T, Jomelli V. Global overview of the geological hazard exposure and disaster risk awareness at world heritage sites. J Cult Herit. 2017;28:151–7.
15. Trovato MG, Ali D, Nicolas J, El Halabi A, Meouche S. Landscape risk assessment model and decision support system for the protection of the natural and cultural heritage in the Eastern Mediterranean Area. Land. 2017;6(4):76.
16. Yu H, Verburg PH, Liu L, Eitelberg DA. Spatial analysis of cultural heritage landscapes in rural China: land use change and its risks for conservation. Environ Manage. 2016;57(6):1304–18.
17. Pham V-M, Van Nghiem S, Van Pham C, Luu MPT, Bui Q-T. Urbanization impact on landscape patterns in cultural heritage preservation sites: a case study of the complex of Huế Monuments. Vietnam Landscape Ecol. 2021;36(4):1235–60.
18. Administration NCH. The third national cultural heritage survey work manual in China. Beijing: Heritage Press; 2007.
19. Guo CY. A study on the protection and development of the Pre-Qin City Sites in Zhengzhou Area. Zhengzhou University; 2014.
20. Chen P, Lu P, Yang S, Storozum M, Yang R, Tian Y, et al. The impact of ancient landscape changes on the city arrangement of the early Shang Dynasty Capital Zhengzhou central China. Front Earth Sci. 2021. https://doi.org/10.3389/feart.2021.656193.
21. Zhou Y. Landscape evaluation and optimization of Zhengzhou Shang-city ruins. Sichuan Agricultural University; 2020.
22. Jiang A, Chen F, Masini N, Capozzoli L, Romano G, Sileo M, et al. Archeological crop marks identified from cosmo-skymed time series: the case of Han-Wei capital city, Luoyang. China Int J Digital Earth. 2017;10(8):846–60.
23. Guoxiang Q. On the layout of the palace-city of the han-wei luoyang city in the light of the changhemen gate. Chinese Archaeol. 2004;4(1):165–9.
24. Team HWLCA. Changhemen gate-site of the Northern Wei Palace-city in Han-Wei Luoyang City Henan. Chinese Archaeol. 2004;4(1):49–56.
25. Cuca B, Hadjimitsis DG. Space technology meets policy: an overview of earth observation sensors for monitoring of cultural landscapes within policy framework for cultural heritage. J Archaeol Sci Rep. 2017;14:727–33.
26. Luo L, Wang X, Guo H, Lasaponara R, Zong X, Masini N, et al. Airborne and spaceborne remote sensing for archaeological and cultural heritage applications: a review of the century (1907–2017). Remote Sens Environ. 2019;232: 111280.
27. Karra K, Kontgis C, Statman-Weil Z, Mazzariello JC, Mathis M, Brumby SP. Global land use/land cover with Sentinel 2 and deep learning. 2021 IEEE International Geoscience and Remote Sensing Symposium IGARSS: IEEE 2021. 2021; 4704–7.
28. Jun C, Ban Y, Li S. Open access to earth land-cover map. Nature. 2014;514(7523):434.
29. Luo D, Ye L, Sun D. Risk evaluation of agricultural drought disaster using a grey cloud clustering model in Henan province, China. Int J Dis Risk Reduct. 2020;49: 101759.
30. National Bureau of Statistics http://www.stats.gov.cn/ Accessed 1 Aug 2022.
31. Wei H, Xue D, Huang J, Liu M, Li L. Identification of coupling relationship between ecosystem services and urbanization for supporting ecological management: a case study on areas along the yellow river of henan province. Remote Sens. 2022;14(9):2277.
32. Liu Y, Zhou Y. Reflections on China's food security and land use policy under rapid urbanization. Land Use Policy. 2021;109: 105699.
33. Sentinel-2 10m Land use/land cover time series. https://www.arcgis.com/home/item.html?id=d3da5dd386d140cf93fc9ecbf8da5e31. Accessed 24 Jun 2022.
34. Satopaa V, Albrecht J, Irwin D, Raghavan B. Finding a" kneedle" in a haystack: detecting knee points in system behavior. 2011 31st international conference on distributed computing systems workshops IEEE 2011; 166–71.
35. Lu P, Tian Y, Yang R. The study of size-grade of prehistoric settlements in the Circum-Songshan area based on SOFM network. J Geog Sci. 2013;23(3):538–48.
36. Yan L, Yang R, Lu P, Teng F, Wang X, Zhang L, et al. The spatiotemporal evolution of ancient cities from the late Yangshao to Xia and Shang Dynasties in the central plains. China Heritage Sci. 2021;9(1):1–16.
37. Li C. A Study on the early city and civilization of the Central Plains. Zhengzhou University; 2016(In Chinese).
38. Chen County in Baidu encyclopedia. https://baike.baidu.com/item/%E9%99%88%E7%95%99%E9%83%A1/7957563?fr=aladdin . Accessed 1 Aug 2022.
39. Qingyang City in Baidu encyclopedia. https://baike.baidu.com/item/%E5%BA%86%E9%98%B3%E5%8F%A4%E5%9F%8E/2716130?fr=aladdin . Accessed 1 Aug 2022.
40. Weiguo City in Baidu encyclopedia. https://baike.baidu.com/item/%E5%8D%AB%E5%9B%BD%E6%95%85%E5%9F%8E/3313578?fr=aladdin. Accessed 1 Aug 2022.
41. World cultural heritage center of China. https://www.wochmoc.org.cn. Accessed 1 Aug 2022.
42. Pan Y, Bai JY, Shi Y. Research on traditional rural landscape zoning and characteristics based on dominant land cover—a case study of the Fulao District in East Guangdong. Chinese Landscape Archit. 2022;38(02):48–53. https://doi.org/10.19775/j.cla.2022.02.0048(InChinese).
43. Wang J-J. Flood risk maps to cultural heritage: measures and process. J Cult Herit. 2015;16(2):210–20.
44. Minos-Minopoulos D, Dominey-Howes D, Pavlopoulos K. Vulnerability assessment of archaeological sites to earthquake hazard: an indicator based method integrating spatial and temporal aspects. Ann Geophys. 2017;60(4):S0445.
45. Cuca B, Agapiou A. Impact of land-use change and soil erosion on cultural landscapes: the case of cultural paths and sites in Paphos district. Cyprus Appl Geomat. 2018;10(4):515–27.
46. Guerriero L, Di Napoli M, Novellino A, Di Martire D, Rispoli C, Lee K, et al. Multi-hazard susceptibility assessment using analytic hierarchy process: the derwent valley mills UNESCO world heritage site case study (United Kingdom). J Cult Herit. 2022;55:339–45.
47. Wang Y. The protection and utilization of the site of Zhengzhou Shang dynasty is discussed. Zhengzhou University 2017(In Chinese).

48. Li WY. A preliminary study on the protective display of the national archaeological site park——taking the national archaeological site of the han dynasty as an example. Res Heritages Preserv. 2018;3(08):121–3. https://doi.org/10.19490/j.cnki.issn2096-0913.2018.08.032.
49. Han-Wei capital city Protection Regulations https://baike.baidu.com/item/%E6%B4%9B%E9%98%B3%E5%B8%82%E6%B1%89%E9%AD%8F%E6%95%85%E5%9F%8E%E4%BF%9D%E6%8A%A4%E6%9D%A1%E4%BE%8B/5294972?fr=aladdin Accessed 29 Aug 2022.
50. Brown CF, Brumby SP, Guzder-Williams B, Birch T, Hyde SB, Mazzariello J, et al. Dynamic World, Near real-time global 10 m land use land cover mapping. Scientific Data. 2022;9(1):251. https://doi.org/10.1038/s41597-022-01307-4.

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